EXPERT REPORT OF RUSSELL E. KEENAN, PH.D.

In the Matter of City of Spokane v. Monsanto Company, Solutia Inc., and Pharmacia LLC in the United States District Court, Eastern District of Washington: Case No. 2:15-cv-00201-smj

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ACRONYMS AND ABBREVIATIONS

95UCL	95th percentile upper confidence limit
ADD	average daily dose
AEHS	Association for Environmental Health and Sciences Foundation
ATSDR	Agency for Toxic Substances and Disease Registry
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act of 1980
CSF	cancer slope factor
Ecology	Washington State Department of Ecology
EPA	U.S. Environmental Protection Agency
EPC	exposure point concentration
HI	hazard index
HQ	hazard quotient
IRIS	Integrated Risk Information System
KM mean	Kaplan-Meier mean
LADD	lifetime average daily dose
LOAEL	lowest-observed-adverse-effect level
MADEP	Massachusetts Department of Environmental Protection
MCL	maximum contaminant level
MEE	microexposure event model
NHANES	National Health and Nutrition Examination Survey
NOAEL	no-observed-adverse-effect level
NRC	National Research Council
OSWER	Office of Solid Waste and Emergency Response
PBDE	polybrominated diphenyl ether
PCB	polychlorinated biphenyl
POD	point of departure
ppb	parts per billion
ppm	parts per million

PRA	probabilistic risk assessment
RCRA	Resource Conservation and Recovery Act
RfD	reference dose
RME	reasonable maximum exposure
SRHD	Spokane Regional Health District
UF	uncertainty factor
WDFW	Washington State Department of Fish and Wildlife
WDOH	Washington State Department of Health
WRIA	Water Resource Inventory Area

1 INTRODUCTION AND ANALYSIS SUMMARY

1.1 PROFESSIONAL QUALIFICATIONS AND SCOPE OF OPINIONS

I am Russell E. Keenan, Ph.D., Vice President and Principal Toxicologist at Integral Consulting Inc., a national science and engineering firm providing interdisciplinary services in health, environment, technology, and sustainability.

I determined that insofar as polychlorinated biphenyls (PCBs) are concerned, the Spokane River is safe for all common, real-world recreational uses of the river, including fish consumption. In developing my opinion, I analyzed and evaluated Spokane River PCB data, including data for surface water, sediment, and fish tissue. I then used conservative and accepted methods for characterizing the safety of the recreational uses of the river. I also examined the fish advisories that have been issued for the Spokane River and replaced generic assumptions with site-specific findings. I determined that current concentrations in fish tissue do not pose an unacceptable risk for human consumption.

I have 30 years of experience specializing in chemical risk assessment and toxicology, with much of my work focusing on assessing human health and ecological risks of chemicals in the environment. In particular, for the past 30 years, I have made or have assisted in making determinations about safe levels of substances in the environment.

Over the past 30 years, I have directed a team of scientists in evaluating the human health and ecological risks associated with chemical exposures at a number of Comprehensive Environmental Response, Compensation and Liability Act (CERCLA, or Superfund) sites, Resource Conservation and Recovery Act (RCRA) facilities, and state-led sites involving multiple exposure pathways. I routinely provide consultation on multistakeholder technical and steering committees, technical expertise and support in regulatory negotiations, and strategic consultation on site-related risks, liability issues, and remedy selection.

I have served as an invited expert on numerous technical and regulatory panels, including several chemical-specific expert review panels for the independent nonprofit organization, Toxicology Excellence for Risk Assessment. In addition, I serve as a subject matter expert to the Sediment Management Work Group / U.S. Army Corps of Engineers Research Program on Fish Exposure Processes at Contaminated Sediment Sites. I currently serve as a member of the Science Advisory Board to the nonprofit Association for Environmental Health and Sciences Foundation (AEHS). I have also testified before U.S. Congressional panels, state environmental boards, and federal and state agencies during regulatory proceedings on environmental issues.

Additionally, I managed the first private sector Cooperative Research and Development Agreement with the U.S. Environmental Protection Agency (EPA) in the field of regulatory

toxicology and risk assessment, which developed Monte Carlo-based models for characterizing the uncertainty in reference dose (RfD) estimates used in noncancer risk assessment. Subsequently, I served as one of the independent experts in the congressionally mandated review of EPA's process for handling toxicological uncertainty in its Integrated Risk Information System, more commonly known by its acronym, IRIS. I have developed time-dependent probabilistic methods for characterizing exposure, which EPA recognized and approved in Superfund guidance. I have authored more than 90 publications in my field. I am an active member in the Society of Toxicology, receiving two best paper awards, and I hold memberships in the Society for Risk Analysis, AEHS, and the National Council for Air & Stream Improvement.

My curriculum vitae is attached to this report as Appendix A.

Integral Consulting is compensated at a rate of $415 per hour for my time in consulting on these matters, preparing this report, and, if called upon to do so, providing testimony in this case.

1.2 CONCLUSIONS

With respect to PCBs, the Spokane River is safe for all common, real-world recreational uses. This includes individuals engaged in both shoreline and water recreational activities such as swimming, wading, sunbathing, picnicking, kayaking, canoeing, rafting, and fishing, and individuals eating fish caught from the river.

When the current fish advisories for the Spokane River are examined in light of real-world, site-specific data, the concentrations of PCBs in fish tissue do not present a safety concern for human consumption. Consistent with my site-specific risk assessment for fish consumption, when the ingestion rates of locally caught fish, preferences for eating different fish species, and differences in fish preparation and cooking methods are considered, there are no unreasonable health risks associated with eating fish from the Spokane River.

Dr. DeGrandchamp's opinions concerning Spokane River fish tissue PCB concentrations, fish advisories, and potential public health concerns, are based on outdated information that misrepresents current conditions that are not relevant to the current river conditions and are based on unsubstantiated consumption rates. Dr. DeGrandchamp's report misrepresents exposures to minority populations and overstates risks to anglers. He also did not perform a risk assessment to support his opinions. As a result, his opinions are speculative and unreliable.

1.3 BASIS OF CONCLUSIONS

The Spokane River is safe to use. Hypothetical risks from PCB exposure are below conservative regulatory risk benchmarks for safety. In formulating my opinion, I conducted a site-specific risk assessment that followed accepted principles of toxicology and used conservative, EPA-approved risk assessment methods when evaluating each activity and use of the river. My risk assessment used Spokane River PCB data for surface water, sediment, and fish tissue. To ensure that risks were not underestimated, I developed conservative contact rates, frequencies, and durations for estimating exposure to water and sediment. I used fish consumption rates that are specific to the region, which also reflect the types of fish species and preparation methods preferred by anglers. Finally, I compared these site-specific estimates of hypothetical exposure to EPA's conservative regulatory benchmarks for PCBs in reaching my conclusions.

In contrast to my site-specific methodology, the fish advisories issued for the Spokane River use a one-size-fits-all preliminary risk calculation. Purely advisory as to their intent, the fish advisories for PCBs, lead, mercury, and polybrominated diphenyl ethers (PBDEs) do not predict the onset of human disease if exceeded. Further discussion concerning fish advisories in relation to the results of my site-specific risk assessment is provided in Section 5 of this report.

1.3.1 Toxicology and Dose-Response

Toxicology is the study of adverse effects of chemical substances on living organisms and their environment. It is a field of science that helps us understand whether a chemical substance in a given situation can be harmful to people, animals, or the environment. The National Institute of Environmental Health Sciences refers to toxicology as the "Science of Safety" because it is a science devoted to studying safety. Toxicology uses the power of science to predict what and how chemicals may cause harm and then shares that information to protect public health.

A fundamental tenet of toxicology is that "the dose makes the poison." This means that risk of harm is not defined devoid of dose levels. From a toxicology perspective, all substances at a certain dose level can be considered hazardous. While one or two aspirins may be good for you, swallowing a bottle of aspirin may be harmful. Indeed, even the ingestion of pure water, at a sufficiently large enough dose, can cause death via kidney failure. The field of toxicology tries to understand and identify at what dose and through what exposure pathways a substance poses a hazard.

Using EPA risk assessment methods, dose is defined as the total amount of chemical absorbed through pathways of exposure. Oftentimes, in risk assessments of PCBs, there are no direct measures of PCB levels in the blood or in adipose tissue to quantify the dose. EPA risk assessment methods use PCB levels in the environment combined with various assumptions concerning hypothetical contact to calculate dose. This part of the risk assessment paradigm is known as the exposure assessment.

Another part of the EPA risk assessment paradigm is the dose-response assessment. Dose response is the evaluation of clinical effects based on increasing dose of a substance. For example, increasing doses of alcohol result in predictable increases in inebriation, loss of coordination, and other effects.

EPA has adopted very conservative, worst-case dose-response assessments for PCBs that portray hypothetical risks as possible when, in reality, none may actually exist. EPA's dose-response assessments and extrapolations to derive the PCB toxicity criteria for hypothetical cancer risks (cancer slope factor [CSF]) and noncancer effects (RfD) are based on a set of assumptions and practices that overestimate risk:

- Findings in high-dose animal studies were extrapolated to humans at much lower exposure levels. In other words, EPA made the conservative assumption that the effects seen in animals exposed to PCBs at levels that humans would never experience would be the same as the effects on humans exposed to much lower levels of PCBs.
- Humans were assumed to be more sensitive to PCBs than animals, even though we know that the opposite is true.
- The hypothetical risks for the most sensitive humans were extrapolated to the entire population, which, of course, overstates even the hypothetical risk for the vast majority of the population.
- Every dose, no matter how small, was assumed to present an increased cancer risk, even though we know that there are thresholds below which effects are not seen, even in high-dose animal studies.

My review of the human and animal PCB literature leads me to conclude that there is no consistent, persuasive evidence that PCBs would cause cancer or other diseases in humans at the levels of exposure that would typically be encountered in the environment, such as the Spokane River. Nevertheless, for my evaluation as to whether the Spokane River is safe to use, I have adopted EPA's dose-response assessments and the hypothetical assumption that PCBs may cause cancer and various noncancer conditions in humans.

1.3.2 Conservative Exposure Assumptions and Risk Assessment Methods

For my evaluation and determination that, with respect to PCBs, the Spokane River is safe for recreational uses, I used EPA risk assessment methods and a series of conservative exposure assumptions to ensure that risks were not underestimated for such pathways as swimming, wading, sunbathing, picnicking, kayaking, canoeing, rafting, and fishing. My conservative assumptions concerning the amount, frequency, and duration of exposures resulted in calculated doses that are at the highest bound of real-world estimates, even though we know

that actual exposures are less for virtually everyone. Consequently, the upper-bound risk estimates that I calculated are hypothetical and overstated, while the real risks may be zero.

For my evaluation of the safety, focusing on PCBs, of eating fish caught from the Spokane River, I used more complete and in-depth EPA methods (probabilistic risk assessment [PRA]) and conservative assumptions. A PRA uses a range of values for individual exposure parameters in place of single point estimates for assessing safety. Furthermore, PRA allows the analyst to capture variable consumption rates of locally caught fish, preferences for eating different fish species, and differences in fish preparation and cooking methods. Whereas fish advisories are based on a one-size-fits-all preliminary risk calculation, my evaluation is complete and conforms to EPA PRA guidance.

1.4 CHARACTERIZATION OF HYPOTHETICAL RISKS AND CONCLUSIONS

Using EPA-accepted risk assessment methods, and all of the conservative assumptions built into them, and the Spokane River PCB data for surface water, sediment, and fish tissue, I calculated hypothetical cancer and noncancer risks for all common, real-world recreational uses of the river, including fish consumption. I used conservative and accepted scientific methods for characterizing the safety of these uses of the river.

As far as the hypothetical and overestimated cancer and noncancer risks from PCBs are concerned, those hypothetical risks of all common recreational uses of the Spokane River are well within the range of risk deemed acceptable by EPA and the State of Washington. The river is safe for intensive recreational activities, such as swimming, wading, sunbathing, picnicking, kayaking, canoeing, rafting, and fishing, and for eating fish caught from the river. Consistent with these findings, when the current fish advisories are examined in light of site-specific data instead of generic assumptions, the concentrations in fish tissue do not present a safety concern for human consumption.

While this methodology allows us to calculate hypothetical risks, I believe the actual risks of cancer and noncancer conditions related to PCBs in the Spokane River are *de minimis* and are in fact zero.

2 OVERVIEW OF HUMAN HEALTH RISK ASSESSMENT PROCESS

EPA examined its risk assessment principles and practices, based on historical and current perspectives, in an important policy document (USEPA 2004a). In that evaluation, EPA provided a common and basic definition for risk assessment as practiced throughout the agency:

> Risk assessment is a process in which information is analyzed to determine if an environmental hazard might cause harm to exposed persons and ecosystems.

As described in detail by EPA (USEPA 2004a), risk assessment is highly interdisciplinary in that it draws from such diverse fields as biology, toxicology, ecology, engineering, geology, statistics, and the social sciences to create a rational framework for evaluating hazards to human health. Risk assessment is also an evolving science in which advancements in these disciplines, and in the practice of risk assessment itself, have led to increased precision in characterizing risks to better inform risk management decisions. Interestingly, EPA's first application of quantitative procedures to a large number of chemicals, and the first EPA document describing quantitative procedures used in risk assessment, was the 1980 *Federal Register* notice announcing the availability of water quality criteria documents for 64 chemicals (USEPA 1980b). Although the water quality criteria document for PCBs (USEPA 1980a) was highly conservative and adopted default values for the exposure parameters and toxicity benchmarks, there were no risk-based ambient water quality criteria prior to its publication. The previous numeric criterion for PCBs was a recommended permissible concentration of 0.001 mg/L, equal to 1,000,000 parts per quadrillion in public water supplies, accompanied by the disclaimer that a defensible recommendation could not be made due to the paucity of available scientific information (NAS 1972).

In characterizing the safety of all common, real-world recreational uses of the Spokane River, I used EPA-accepted, scientific risk assessment methods and PCB data for the Spokane River surface water, sediment, and fish tissue. The approach taken in my risk assessment is consistent with the approach and risk assessment framework recommended by the National Research Council (NRC) of the National Academies of Sciences (NRC 1983). The NRC framework for characterizing potential human health risks was subsequently adopted by EPA. Consequently, in conducting this risk assessment, the following EPA guidance and policy documents were also considered and followed:

- *Risk Assessment Guidance for Superfund, Volume 1, Part A* (USEPA 1989)
- *Office of Solid Waste and Emergency Response (OSWER) Directive 9285.6-03, Human Health Evaluation Manual* (USEPA 1991)

- *Final Guidelines for Exposure Assessment* (USEPA 1992a)
- *Guidance on Risk Characterization for Risk Managers and Risk Assessors* (USEPA 1992b)
- *OSWER Directive 9285-16. Use of IRIS Values in Superfund Risk Assessment* (USEPA 1993)
- *Guidance for Risk Characterization* (USEPA 1995)
- *Policy for Use of Probabilistic Analysis in Risk at the U.S. Environmental Protection Agency* (USEPA 1997)
- *Risk Assessment Guidance for Superfund: Volume 3, Part A – Process for Conducting Probabilistic Risk Assessment* (USEPA 2001)
- *OSWER Directive 9285.6-10. Calculating Upper Confidence Limits for Exposure Point Concentrations at Hazardous Waste Sites* (USEPA 2002a)
- *A Review of the Reference Dose and Reference Concentration Process* (USEPA 2002b)
- *OSWER Directive 9285.7-53. Human Health Toxicity Values in Superfund Risk Assessments* (USEPA 2003)
- *An Examination of EPA Risk Assessment Principles and Practices* (USEPA 2004a)
- *Risk Assessment Guidance for Superfund – Part E, Supplemental Guidance for Dermal Risk Assessment* (USEPA 2004b)
- *Guidelines for Carcinogen Risk Assessment* (USEPA 2005)
- *Risk Assessment Guidance for Superfund – Part F, Supplemental Guidance for Inhalation Risk Assessment* (USEPA 2009a)
- *Using Probabilistic Methods to Enhance the Role of Risk Analysis in Decision-Making with Case Study Examples* (USEPA 2009b)
- *Exposure Factors Handbook* (USEPA 2011*)*
- *OSWER Directive 9200.1-120* (USEPA 2014).

The NRC and EPA risk assessment framework embodies a tiered approach to the analysis and evaluation of safety to provide the flexibility needed to match the complexity of the site and hypothetical exposure pathways. A screening-level risk assessment is commonly used to identify chemicals and media (e.g., sediment, fish tissue, water) that may have the potential to result in unacceptable risks and thus require further evaluation. USEPA (1992a) reports that screening-level evaluations provide bounding estimates, the purpose of which is to "eliminate further work on refining estimates for pathways that are clearly not important." According to EPA, the approach is to select a set of values in the dose estimate that "will result in an exposure or dose higher than any exposure or dose expected to occur in the actual population. The estimate of exposure or dose calculated by this method is clearly outside of (and higher than)

the distribution of actual exposures or doses. If the value of this bounding estimate is not significant, the pathway can be eliminated from further refinement."

By design, screening assessments use highly conservative default exposure parameters and assumptions in an effort to determine whether there is a need to conduct more detailed and refined risk assessments that consider site-specific information. For the Spokane River, these types of conservative default assumptions might include the following:

- The assumption that individuals may be exposed to the highest chemical concentrations in sediment, surface water, or fish tissue for extended periods of time
- The assumption that individuals will eat only the species of fish with the highest chemical concentrations, at high rates, throughout their lifetimes
- The assumption that individuals will have intensive contact with sediment and surface water frequently.

If the screening-level assessment determines that there are no potentially unacceptable risks under these hypothetical assumptions, then there is no need to complete a more refined assessment. On the other hand, if the screening-level assessment indicates that hypothetical levels of risk may potentially exceed the regulatory target risk range, then a more detailed analysis is conducted to refine the hypothetical risk estimates.

Refined risk assessments may also be undertaken in stages. The first stage generally involves a refinement of individual exposure parameters to more accurately reflect the behaviors of the potentially exposed population. This approach estimates risks using a combination of upper-bound and central tendency exposure parameters, thereby increasing the likelihood that the parameters, when combined, will be representative of some segment of the hypothetically exposed population. In this stage, single estimates are used for each parameter (e.g., sediment concentration, exposure duration), and single estimates of risks and hazards are recalculated.

If this approach indicates that hypothetical levels of risk may potentially exceed the regulatory target risk range, then further refinement is often undertaken through the use of more complete and in-depth EPA methods known as Probabilistic Risk Assessment (PRA). The PRA approach is a computerized, mathematical technique used in many science, engineering, and social science disciplines. It furnishes the decision maker with a range of possible outcomes and the probabilities associated with each outcome occurring.

In human health risk assessment, a PRA simulation is used to build models of possible results by substituting a range of values (i.e., a probability distribution) for any factor in the risk assessment equation that has inherent variability. During a PRA simulation, values are sampled at random from the input probability distributions. Each set of samples that is selected and run through the risk assessment equation is called an iteration, and the calculated result of that iteration is recorded. The PRA simulation then calculates the risks over and over again,

each time using a different set of values selected at random from the input probability distributions. A PRA simulation could involve thousands or tens of thousands of iterations before it is complete. The results of all of these repeated calculations are compiled in a final distribution of possible outcome values. In this way, a PRA simulation provides a much more comprehensive view of what may happen as well as its likelihood of occurrence.

In other words, the PRA approach provides an estimate of the likelihood or probability of risk associated with the entire range of exposure. According to EPA's guiding principles, a PRA is useful when screening-level risk estimates are above levels of concern (USEPA 1997). This approach replaces all or selected single estimates of exposure parameters with a range of values to capture the variability within a population. The output of a PRA is a full range of hypothetical risk estimates for a given population.

In addition, USEPA (1997) points out that a PRA is useful:

> ...when it is necessary to disclose the degree of bias associated with point estimates of exposure; when it is necessary to rank exposures, exposure pathways, sites or contaminants; when the cost of regulatory or remedial action is high and the exposures are marginal; or when the consequences of simplistic exposure estimates are unacceptable.

EPA's *Risk Assessment Guidance for Superfund: Volume 3, Part A –Process for Conducting Probabilistic Risk Assessment* further describes this tiered approach for evaluating potential health risks (USEPA 2001). This guidance describes a process that begins with a simple point estimate approach (deterministic risk assessment) and progresses, if warranted, onto increasingly complete but more complex tiers of probabilistic analysis. Implicit in the move from deterministic to probabilistic analysis is the realization that simple point estimates are not an adequate means for basing risk management decisions in complex situations.

Such a phased approach was used to evaluate potential exposures for the Spokane River. A simple deterministic risk assessment was conducted to determine whether consideration of representative assumptions and parameters would result in *de minimis* risk estimates for potential exposures to sediments and surface water. Given that some of the PCB concentrations in fish tissue collected from the Spokane River exceeded the fish advisory levels (Section 5), an in-depth PRA was conducted for the fish consumption pathway. These analyses form the bases for my opinions.

In contrast to the conservative and site-specific risk assessment methods that I used to inform my opinion that the Spokane River is safe regarding the presence of PCBs, none of the plaintiffs' experts (Drs. Olsen, Markowitz, Rosner, Carpenter, Rodenburg, and DeGrandchamp) conducted a scientific risk assessment to support his or her assertions concerning PCBs and health risks. By simple reference to fundamental principles, the risk of harm from PCBs cannot

be defined devoid of dose levels. Unless PCB dose levels are either measured or quantified through exposure modeling, such assertions of harm are pure conjecture.

3 REVIEW OF TOXICITY VALUES FOR PCBs

My evaluation of the safety of the Spokane River for recreational uses relies upon EPA's conservative dose-response assessments and the hypothetical assumption that PCBs may cause cancer and various noncancer conditions in humans. This analysis follows federal- and state-recommended risk assessment protocols, including the use of regulatory toxicological criteria designed to ensure that public health is protected.

For PCBs, regulatory toxicological criteria are developed using laboratory animal studies in which either tumors (including benign lesions) are an outcome or precancer conditions are observed. For chemicals that are considered to have the potential to cause noncancer health effects, toxicological criteria are based on the indicator of an adverse health effect elicited at the lowest dose. For either cancer or noncancer, the dose level at which no adverse effects are observed, or the lowest dose tested at which adverse effects are observed, is the point of departure (POD) for developing toxicological criteria.

The RfD is the toxicity value used to assess potential noncancer risks to humans from chemicals. EPA defines the chronic RfD as follows:

> An estimate (with uncertainty spanning perhaps an order of magnitude) of a daily oral exposure for a chronic duration (up to a lifetime) to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious effects during a lifetime. It can be derived from a NOAEL, LOAEL, or benchmark dose, with uncertainty factors generally applied to reflect limitations of the data used (USEPA 2019b).

EPA has established guidance for deriving an RfD (USEPA 2002b). Potential toxicity to humans is evaluated by examining toxicity data from laboratory animal species. Available literature is reviewed for selecting the key study on which to base the quantitative derivation of the RfD, based on study quality and adherence to general good laboratory practices and standards. Critical effects from the studies are identified to define the POD. Relative uncertainty factors (UFs), sometimes referred to as safety factors, are applied to the POD to calculate the final RfD. The UFs are intended to account for limitations of the underlying data and to ensure that the RfD is unlikely to result in adverse health effects in exposed human populations.

There are five UFs used by EPA in human health risk assessment: UF_D for uncertainty in the underlying database; UF_H to account for sensitive individuals; UF_A for uncertainty associated with extrapolating from animal studies to humans; UF_{SC} for uncertainty associated with relying on a subchronic toxicity study rather than a long-term (chronic) toxicity study; and UF_L if the derivation relied on the lowest-observed-adverse-effect level (LOAEL) rather than the no-observed-adverse-effect level (NOAEL). These five UFs are multiplied by one another to derive

a composite factor, designated as UF_C. Therefore, the RfD is derived using the following equation (USEPA 2002b):

$$RfD = \frac{POD}{UF_C}$$

Where:

POD = point of departure (mg/kg-day)

UF_C = uncertainty factor (composite).

To assess the potential cancer effects to humans from chemical exposures, EPA typically develops CSFs. CSFs estimate the incremental risk of developing cancer based on a lifetime of exposure under the conservative assumption that every dose, no matter how small, presents an increased risk of cancer. This assumption disregards the scientific evidence that dose thresholds exist, below which effects are not seen, even in the high-dose animal studies.

3.1 AROCLOR 1254 REFERENCE DOSE

The lowest doses producing PCB-related adverse health effects identified in the literature were those observed in the studies of rhesus monkeys performed by Arnold et al. (1993a,b, 1995) and Tryphonas et al. (1989, 1991a,b) with Aroclor 1254. These studies describe different toxicological endpoints for the same cohort of monkeys, and were selected by EPA as the critical studies for deriving the chronic PCB RfD.

EPA established an oral RfD of 2×10^{-5} mg/kg-day (20 ng/kg-day) for Aroclor 1254. This RfD is based on a LOAEL of 0.005 mg/kg-day (5,000 ng/kg-day) as the POD for both dermal/ocular effects and immune system changes reported in these monkeys (Arnold et al. 1993a,b; Tryphonas et al. 1989, 1991a,b). EPA applied a composite UF of 300, which includes a UF of 10 to account for sensitive individuals, a UF of 3 for interspecies extrapolation, a UF of 3 for LOAEL to NOAEL, and a UF of 3 for subchronic to chronic.

For the specific situation of evaluating subchronic exposures, which EPA defines as having an exposure duration of 7 years or less, I used EPA's subchronic oral RfD of 5×10^{-5} mg/kg-day (50 ng/kg-day) for Aroclor 1254 (USEPA 1994). EPA estimated the subchronic oral RfD by modifying the chronic oral RfD. Both RfDs are based on the same cohort of rhesus monkey studies (Arnold et al. 1993a,b, 1995; Tryphonas et al. 1989, 1991a,b).

Substantial scientific arguments can be made that the UFs for study duration and animal to human extrapolation should be reduced from their current values.

3.1.1 Animal to Human Extrapolation Uncertainty (UF_A)

In deriving the RfD for Aroclor 1254, USEPA (2017a) applied a UF of 3 for interspecies extrapolation (monkey to human), based on the premise of broadly similar physiological and metabolic processes between primates and humans and that the UF of 3 would afford protection to humans when relying upon data derived from primates. Although this assumption may appear to be reasonable at first inspection, a species comparison of exposure and health effects data for PCBs reveals that rhesus monkeys are actually more sensitive than humans to the noncancer effects of PCBs.

First, a direct comparison of the relative sensitivity of humans and primates to the effects of PCBs is based on clinical signs and symptoms. The absence of dermal and ocular effects in highly exposed humans in occupational studies where blood PCB levels were measured is compared to the observation of these effects in the rhesus monkey studies. The pattern of nail, dermal, and ocular effects seen in primates was not observed in humans following occupational exposure to high levels of PCBs (Smith et al. 1982; Wolff et al. 1982; Lawton et al. 1985; Emmett et al. 1988a,b). Blood serum PCB levels measured in rhesus monkeys ranged from 19 parts per billion (ppb) in the lowest dose test group, which represents the LOAEL, to 218 ppb in the highest group tested (Arnold et al. 1993a,b, 1995; Mes et al. 1989; Tryphonas et al. 1989, 1991a,b). These levels in monkeys are substantially less than those seen in the worker cohorts, where average blood PCB concentrations exceeded 400 ppb and ranged as high as 3,250 ppb in some individuals (Lawton et al. 1985; James et al. 1993). This provides clinical evidence indicating that monkeys are more sensitive to the effects of PCBs.

The adverse effects that underpin the EPA RfD are mediated by the aryl-hydrocarbon receptor (Silkworth et al. 2005; Sutter et al. 2010). Recently, some members of the World Health Organization panel that developed the toxicity equivalence factors for dioxin-like compounds recommended that the relative potency of some PCB congeners be lowered nearly 100-fold based on data using human cells (Larsson et al. 2015). The adverse effects observed in sensitive laboratory animals that are mediated by the aryl-hydrocarbon receptor are unlikely to be found in humans unless their PCB doses are much higher.

There is growing evidence that humans are far less sensitive than are rhesus monkeys to the effects of identical Aroclor 1254 exposures. Silkworth et al. (2005) reported that rhesus monkey hepatocytes were 1,000 times more responsive than fresh human hepatocytes to the induction of messenger RNA for the Cyp1A1 enzyme. Similar results were reported for human keratinocytes. Carlson et al. (2012) compared the species-specific dose-responses of human and rhesus monkey keratinocytes to Aroclor 1254 exposure in cell culture. They showed that humans are approximately 1,000-fold less sensitive than are rhesus monkeys to Cyp1A1 messenger RNA induction by Aroclor 1254.

In summary, studies of rhesus monkeys and human worker cohorts and the recent studies in cell culture point to the conclusion that rhesus monkeys are at least 10- to 100-fold more sensitive to the dermal, ocular, and immunologic effects of PCBs than are humans. Consequently, there is no justification for applying an interspecies UF of 3 in developing a health-protective RfD. In fact, an interspecies UF of *less than* 1 (i.e., $UF_A = 0.1$ as a conservative estimate) is supported by the data and is justified for use in deriving a chronic RfD for PCBs.

Even Dr. DeGrandchamp acknowledges, in a study conducted for the U.S. Navy, "… if the laboratory species used in toxicological experiments was actually *more* sensitive to a chemical than humans … introducing uncertainty factors into the RfDi would be ultraconservative, since the unaltered NOAEL already represents a conservative estimate of the toxic potential of the chemical with respect to human exposures." Further, "to simply divide the NOAEL by a factor … would compound the conservatism" (DeGrandchamp and Pyatt 2001 at p. 21).

3.1.2 Subchronic to Chronic Duration Extrapolation (UF_{SC})

When a shorter than chronic study is used to define a chronic RfD, EPA's guidance for deriving an RfD (USEPA 2002b) considers the uncertainty associated with extrapolating a subchronic study to a chronic study. This is common practice to allow a risk assessment to be conducted even in the absence of chronic data, and, in fact, studies have shown that this UF actually overpredicts the potential increase in sensitivity from longer-term exposures (Dourson et al. 1996). In deriving the Aroclor 1254 RfD, USEPA (2017a) selected a subchronic to chronic UF of 3 to adjust for study duration. This factor is intended to account for uncertainties related to less-than-chronic exposure and assumes that longer exposure durations would result in more pronounced adverse health effects. However, evidence from the critical animal study demonstrates that the UF for study duration is not warranted. The monkeys were dosed for greater than 25 percent of their lifetimes and, as reported by Arnold et al. (1993a,b) and Tryphonas (1995), a qualitative pharmacokinetic equilibrium had been established in 90 percent of the monkeys with respect to PCB concentrations in adipose tissue and blood. This information indicates that the study should be considered equivalent to a chronic study and that no adjustment for exposure duration is necessary in calculating the PCB RfD.

In assessing the dose-response relationship of PCBs, pharmacological principles reveal that internal measures of dose (e.g., tissue dose, body burden) are preferable to estimates of daily intake (Aylward et al. 1996; USEPA 2000a). Dose metrics based on internal dose can be used to compare responses across species as these parameters take into account species differences in clearance rates (Grassman et al. 1998). The noncancer effects of concern for chronic PCB exposure are related to the concentration of PCBs in tissue or blood. For example, data for rhesus monkeys show that dermal and ocular effects of PCBs are reversible and that health status improves as tissue PCB levels decrease during a recovery period where dosing was terminated (Allen et al. 1980; Barsotti 1980). Therefore, clinical health effects of PCB exposure would not be expected to worsen once PCB equilibrium is achieved.

In summary, a subchronic to chronic UF of 1 is supported by the data and is justified for use in deriving a chronic RfD for PCBs.

3.1.3 Calculation of a Revised RfD for Aroclor 1254

USEPA (2017a) applied a NOAEL to LOAEL UF of 3 to derive the RfD for Aroclor 1254 rather than a full factor of 10 because the critical effects upon which the RfD is based (dermal, ocular, immunological) are considered less serious and do not warrant a full UF of 10. USEPA (2017a) applied a database UF of 1 because there is available information in at least two different species, including studies that examined potential developmental and reproductive toxicity. An interindividual UF of 10 was applied to account for extrapolation from a typical human population to a sensitive subpopulation. These factors are conservative and health-protective UFs and can be used to derive a revised chronic RfD for PCBs.

To calculate a revised chronic RfD for Aroclor 1254, a conservative, data-derived interspecies uncertainty factor of 0.1 ($UF_A = 0.1$) could be combined with a subchronic-to-chronic uncertainty factor of 1 ($UF_{SC} = 1$), along with the other uncertainty factors currently used by EPA (UF_L of 3 for NOAEL to LOAEL, UF_D of 1 for uncertainty in the database, and UF_H of 10 for sensitive individuals), for a total UF_C of 3. Instead of dividing the Aroclor 1254 LOAEL by the current EPA UF_C of 300 to arrive at the current chronic RfD established by EPA of 2×10^{-5} mg/kg-day (20 ng/kg-day), the use of a data-derived UF_C of 3 leads to an RfD of 2×10^{-3} mg/kg-day (2,000 ng/kg-day), 100 times higher than the current RfD.

Although I have illustrated the derivation of a scientific-based and health-protective chronic RfD for PCBs, I have adopted EPA's RfD for my evaluation as to whether the Spokane River is safe to use. If I apply the revised, more-scientifically appropriate RfD, the noncancer risks calculated herein would decrease 100-fold.

3.2 PCB CANCER SLOPE FACTOR

A comprehensive chronic toxicity feeding study of four Aroclor mixtures was completed in 1996, and the findings associated with the tumor incidence segment of the study were published soon thereafter (Mayes et al. 1998). Interestingly, PCB-exposed treatment groups showed greater survival than controls, even though an increase in hepatic tumors was observed for each PCB mixture. The hepatic tumors induced were mostly benign adenomas (80 percent) and did not curtail the animals' life span relative to that of the controls. Moreover, the rate of spontaneous mammary tumors in PCB-exposed females was decreased, and may have improved the survival of these animals.

When EPA conducted its latest evaluation of the tumorigenicity of PCBs (USEPA 1996), it relied heavily upon this study in developing CSFs for each of the Aroclors and for defining a range of CSFs for evaluating the hypothetical risk of exposure to PCBs. USEPA (1996) concluded that

the exposure of female rats to Aroclors 1260, 1254, 1242, and 1016 resulted in liver tumors. Liver tumors were also observed in male rats exposed to Aroclor 1260. USEPA (2017b) reported that in evaluating the potential toxicity of these four mixtures of PCB congeners, it considered all of the PCBs that were likely to be found in the environment. EPA also acknowledged that because of the different chemical and physical properties among the various PCBs, their fate, transport, and environmental persistence varied (USEPA 2017b). As a result, USEPA (2017b) developed a range of CSFs to be used to evaluate PCB mixtures that depends upon the media in which the PCBs are present and the degree of chlorination.

EPA's upper bound CSF of 2 $(mg/kg\text{-}day)^{-1}$ and central estimate CSF of 1 $(mg/kg\text{-}day)^{-1}$ are used for situations where there is a possibility for high risk and persistence. These include food chain exposures; ingestion of soil or sediment; inhalation of dust or aerosols; dermal exposure when an absorption factor has been applied; if there is a presence of dioxin-like, tumor-promoting congeners; and early life exposures (USEPA 2017b). The upper-bound CSF of 0.4 $(mg/kg\text{-}day)^{-1}$ and central estimate CSF of 0.3 $(mg/kg\text{-}day)^{-1}$ are used in situations of low risk and persistence. These include ingestion of water-soluble congeners, inhalation of evaporated congeners, and dermal exposures when no absorption factor has been applied. Lastly, the upper-bound CSF of 0.07 $(mg/kg\text{-}day)^{-1}$ and central estimate CSF of 0.04 $(mg/kg\text{-}day)^{-1}$ are used in situations of lowest risk and persistence. This includes the situation where congeners with more than four chlorines comprise less than 0.5 percent of the total PCBs (USEPA 2017b). According to EPA, central estimates can be used to describe "a typical individual's risk" and "are useful for estimating aggregate risk across a population," while upper bounds provide assurance that this risk is not likely to be underestimated if the underlying model is correct.

EPA's derivation of PCB CSFs is based on linear extrapolations from the bioassay data using a non-threshold dose-response model (USEPA 1996; Cogliano 1998). Because the use of a linear approach presumes that exposure to even a trace quantity of PCBs is associated with some finite level of risk, the resulting cancer risk estimates associated with low-level environmental exposures are many times greater than those that would result from using a nonlinear extrapolation or one based on a threshold mode-of-action.

EPA has adopted very conservative, worst-case dose-response assessments for PCBs. Both the RfD for noncancer effects and the CSF for hypothetical cancer risks are based on a set of assumptions and practices that overstate risk by a vast margin. My review of the human and animal PCB literature leads me to conclude that there is no consistent, persuasive evidence that PCBs would cause cancer or other diseases in humans at the levels of exposure that would be encountered in the environment. Nevertheless, for my evaluation as to whether the Spokane River is safe to use, I have adopted EPA's current dose-response assessments and the hypothetical assumption that PCBs may cause cancer and various noncancer conditions in humans.

4 CONCLUSIONS

I was asked to determine whether the Spokane River is safe to use insofar as PCBs are concerned. In developing my opinion, I analyzed and evaluated the Spokane River PCB data, including data for surface water, sediment, and fish tissue. I then used conservative and accepted methods for characterizing safety for all common recreational uses of the river. With respect to PCBs, the Spokane River is safe for intensive recreational activities such as swimming, wading, sunbathing, picnicking, kayaking, canoeing, rafting, and fishing, and for eating fish caught from the river.

To support my conclusions, I conducted a human health risk assessment to estimate the likelihood that humans engaged in intensive recreational use of the river may be adversely affected by PCBs. While nearly all substances may be toxic at certain levels, the risk of adverse effects occurring is not appreciable unless there is adequate exposure to reach a dose level where toxicity is observed. Thus, it is not only important to consider the toxicity of a given substance, but also the hypothetical doses that may reasonably be anticipated to occur, in order to determine whether the substance presents a meaningful risk of harm to people in a particular setting. The human health risk assessment quantifies estimates of potential chemical exposures resulting in calculated doses and determines the potential for adverse health effects resulting from those exposures.

For my evaluation of the safety associated with PCB exposures that might hypothetically occur during recreational uses of the Spokane River, I used EPA risk assessment methods and a series of conservative assumptions to ensure that risks were not underestimated. I was asked to evaluate the safety of individuals engaged in recreational activities that might involve direct contact with sediment and/or surface water in the Spokane River. During these activities, individuals could hypothetically be exposed to low concentrations of PCBs that are adsorbed to sediment particles in the river. I have considered the possibility that the sediment might contact the skin, and if hand-to-mouth contact occurs, some sediment might be ingested. In addition, if there are trace levels of PCBs dissolved in surface water or adhered to sediment particles, I have considered the possibility of individuals having skin contact with PCBs while swimming or engaging in other water activities such as kayaking or canoeing. These individuals also might incidentally ingest PCBs if they inadvertently swallow water during these water activities.

For my evaluation of the safety, with respect to PCBs, of eating fish caught from the Spokane River, I used more complete and in-depth EPA methods and conservative assumptions than the simpler approach used to evaluate the direct uses of the river. I performed a PRA, which uses a range of values because it is a more in-depth scientific characterization of hypothetical risks and is more complete than the simpler approach, in which single point estimates are selected to represent each exposure parameter. Furthermore, a PRA allows the analyst to capture variable consumption rates of locally caught fish, preferences for eating different fish species, and

differences in fish preparation and cooking methods. Whereas fish advisories are based on a one-size-fits-all preliminary risk calculation, my evaluation is complete and conforms to EPA PRA guidance.

4.1 ASSESSMENT AREAS

The Washington State portion of the Spokane River consists of the Middle Spokane River and the Lower Spokane River, which correspond to the Washington State Department of Ecology (Ecology) Water Resource Inventory Areas (WRIAs) 57 and 54, respectively (Figure 4-1). The Spokane River can be separated into multiple reaches by dam locations throughout its length: Post Falls Dam (near the Idaho border) to Upriver Dam, Upriver Dam to Nine Mile Dam, Nine Mile Dam to Long Lake Dam (also known as Long Lake or Lake Spokane), and Long Lake Dam to the Lake Roosevelt juncture (i.e., the Spokane Arm of Lake Roosevelt). These reaches correspond to those shown on the Washington State Department of Health (WDOH; 2009) fish consumption advisory map, with the following modifications:

- The Upper Falls Dam and Monroe Street Dam within the City of Spokane are located within the Upriver Dam to Nine Mile Dam reach.
- Only one sediment sample was collected between Long Lake Dam and Little Falls Dam, located at River Mile 29,[1] so a separate subarea bounded downstream by Little Falls Dam was not developed.

For my risk assessment, I evaluated hypothetical risks on a river-wide basis and also by the four reaches, or subareas. Each of the river reaches differs with respect to the range of PCB concentrations and potentially offers a different set of available recreational activities. However, while sufficient PCB data are available for the development of reach-specific exposure point concentrations (EPCs), reach-specific human activity data are not available for every reach. Therefore, I used the same hypothetical human exposure parameter values between reaches but used reach-specific PCB data.

Lake Roosevelt is contained within three Ecology WRIAs (Upper, Middle, and Lower). Only those samples collected from within Lower Lake Roosevelt (WRIA 53) and the southern portion of Middle Lake Roosevelt (WRIA 58) were included in my assessment. The evaluated boundaries within Lake Roosevelt extend from the Grand Coulee Dam north (upstream) to Barnaby Island.[2] These bound the location where the Spokane River discharges to Lake Roosevelt.

[1] https://www.nwcouncil.org/reports/columbia-river-history/spokaneriver

[2] The GIS latitude and longitude coordinates are 47.956 and -118.981 for the Grand Coulee Dam and 48.437 and -118.216 for Barnaby Island.

4.2 DIRECT CONTACT WITH SEDIMENT AND SURFACE WATER

The Spokane River offers a variety of outdoor recreational opportunities. The river is a popular destination for kayaking, canoeing, and rafting.[3] Riverside State Park is a 10,000-acre camping park located just north of the city of Spokane.[4] This park, which also includes Nine Mile Recreation Area, offers many uses, including swimming, camping, picnicking, and fishing.

Based on the recreational uses for the Spokane River, I evaluated direct contact with sediment and surface water for three exposure scenarios:

- Shoreline recreation—A number of recreational activities can occur along the shoreline, such as wading, swimming, picnicking, and sunbathing. I selected swimming as the activity to represent shoreline recreation, because the potential for exposure to surface water and sediment is more likely for swimming than for other shoreline activities.
- Water recreation—Due to the popularity of the Spokane River for water activities, such as kayaking, canoeing, and rafting, I selected kayaking as the activity to represent water recreation.
- Recreational/sport fishing—Because fishing is also popular, I evaluated potential exposures for individuals fishing along and within the Spokane River.

For the shoreline and water recreation scenarios, I evaluated hypothetical exposures from skin contact with and incidental ingestion of sediment and surface water. For the recreational/sport fishing scenario, I evaluated exposures from skin contact with and incidental ingestion of sediment, and skin contact with surface water. I did not quantify incidental ingestion of surface water for the recreational/sport fishing scenario, because it is unlikely that appreciable incidental ingestion of surface water would occur during fishing activities.

4.2.1 Exposure Equations for Direct Contact with PCBs in Sediment and Surface Water

To estimate potential exposures and risks due to contact with sediment and surface water, the following exposure equations were used. Exposure parameters that are common to each equation are defined once. For example, body weight (BW) appears in each equation, but is only defined in the first of the following equations:

[3] https://my.spokanecity.org/recreation/outdoor/
https://www.visitspokane.com/things-to-do/recreation/
[4] https://www.tripsavvy.com/outdoor-fun-in-spokane-washington-1609036

Intake via Ingestion of Sediment

$$I_{sed} = \frac{C_{sed} \times IR_{sed} \times BA_{sed} \times FI_{sed} \times EF_{sed} \times ED \times CF}{BW \times AT}$$

Where:

I_{sed}	=	intake, the mass of a chemical absorbed from sediment by the receptor per unit body weight per unit time (mg/kg-day)
C_{sed}	=	chemical concentration in sediment contacted over the exposure period (i.e., EPC for sediment) (mg/kg or parts per million [ppm])
IR_{sed}	=	sediment ingestion rate (mg/day)
BA_{sed}	=	bioavailability adjustment for sediment (percent as fraction)
FI_{sed}	=	fraction of total daily intake of sediment that is site-related (percent as fraction)
EF_{sed}	=	exposure frequency for sediment contact (days/year)
ED	=	exposure duration (years)
CF	=	conversion factor (1×10^{-6} kg/mg)
BW	=	body weight (kg)
AT	=	averaging time (days)

Dermal Absorbed Dose via Contact with Sediment

$$DAD_{sed} = \frac{C_{sed} \times AF_{sed} \times ABS_{d} \times CF \times SA_{sed} \times EF_{sed} \times FI_{sed} \times ED \times EV_{sed}}{BW \times AT}$$

Where:

DAD_{sed}	=	dermal absorbed dose from sediment (mg/kg-day)
AF_{sed}	=	adherence factor for sediment (mg/cm^2)
ABS_{d}	=	dermal absorption factor for sediment (percent as fraction)
SA_{sed}	=	skin surface area available for contact with sediment (cm^2)
EV_{sed}	=	event frequency for sediment (day^{-1})

Intake via Ingestion of Surface Water

$$I_{sw} = \frac{C_{sw} \times IR_{sw} \times BA_{sw} \times FI_{sw} \times EF_{sw} \times ED \times ET_{sw}}{BW \times AT}$$

Where:

I_{sw}	=	intake, the mass of a chemical in surface water absorbed by the receptor per unit body weight per unit time (mg/kg-day)
C_{sw}	=	chemical concentration in surface water contacted over the exposure period (i.e., EPC for surface water) (mg/L or ppm)
IR_{sw}	=	surface water ingestion rate (L/hour)
BA_{sw}	=	bioavailability adjustment for surface water (percent as fraction)
FI_{sw}	=	fraction of total daily intake of surface water that is site-related (percent as fraction)
EF_{sw}	=	exposure frequency for surface water contact (days/year)
ET_{sw}	=	exposure time for surface water contact (hours/day)

Dermal Absorbed Dose via Contact with Surface Water

$$DAD_{sw} = \frac{DA_{event} \times EV_{sw} \times ED \times EF_{sw} \times SA_{sw}}{BW \times AT}$$

And:

$$DA_{event} = 2 \times FA \times K_p \times C_{sw} \times \sqrt{\frac{6 \times \tau_{event} \times t_{event}}{\pi}}$$

Where:

DAD_{sw}	=	dermal absorbed dose from surface water (mg/kg-day)
EV_{sw}	=	event frequency for surface water (events/day)
SA_{sw}	=	skin surface area available for contact with surface water (cm^2)
FA	=	fraction absorbed (percent as fraction)
K_p	=	chemical-specific permeability coefficient (cm/hour)
C_{sw}	=	chemical concentration in surface water contacted over the exposure period (converted to mg/cm^3)
τ_{event}	=	chemical-specific lag time per event (hour/event)
t_{event}	=	event duration (hour/event)

4.2.2 Age Groups Evaluated

For the shoreline and water recreation scenarios, I evaluated three age groups: young children of ages 1 through 6 years, older children of ages 7 through 17 years, and adults 18 years and older. I considered young children because they tend to ingest more on a per body weight basis than older children or adults due to more frequent mouthing behaviors during the early years. For the recreational fishing scenario, I assumed that an older child is likely to engage in fishing activities more frequently than the young child; therefore, I evaluated older children of ages 7 through 17 years and adults. Age-specific exposure parameters were developed for each age group as appropriate.

Descriptions of the age-specific exposure parameters incorporated in the previously presented equations are included below. Exposure parameters common across exposure pathways are discussed first, followed by pathway-specific parameters.

4.2.3 Common Parameters for the Direct Contact Exposure Routes

The exposure parameters that are common include sediment ingestion rates, body weights, exposure durations, averaging times, and EPCs for sediment and surface water. Discussion of these common parameters is presented in the following sections and the parameter values are summarized in Table 4-1. Whenever possible, I have relied on standard EPA values.

4.2.3.1 Sediment Ingestion Rates (IR_{sed})

USEPA (2014) provides default rates for incidental soil ingestion for young children and adults of 200 and 100 mg/day, respectively. EPA guidance does not, however, provide default incidental ingestion rates for sediment. In the absence of data on specific ingestion rates for sediment, I used the soil ingestion rates of 200 and 100 mg/day for young children and adults, respectively, to represent hypothetical sediment ingestion rates as a conservative default approach. For the older child, I assumed an ingestion rate of 100 mg/day, similar to the adult.

4.2.3.2 Body Weight (BW)

USEPA (2004b) recommends that mean age-specific body weights be used in risk assessment. USEPA (2011) provides mean values for body weight by age, based on data collected from the 1999–2006 National Health and Nutrition Examination Survey (NHANES). I have adopted the age-specific mean body weights from this source for this risk assessment, including body weights of 11.4 kg for children aged 1 to <2 years, 13.8 kg for children aged 2 to <3 years, 18.6 kg for children aged 3 to <6 years, 31.8 kg for children aged 6 to <11 years, 56.8 kg for children aged 11 to <16 years, 71.6 kg for individuals aged 16 to <21 years, and 80 kg for adults. I incorporated these age-specific values into time-weighted averages to result in estimated mean body weights

of 19 kg for young children and 50 kg for older children. I used the recommended 80-kg adult body weight to evaluate adult exposures (USEPA 2014).

4.2.3.3 Exposure Duration (ED)

The exposure duration is the number of years over which an exposure occurs. USEPA (2014) recommends 26 years as the upper bound estimate of residence time. Although not all of the recreational users of the Spokane River are residents who live along the river, I used the residence time as a surrogate for recreational exposure duration in this analysis.

The estimate of 26 years represents the total residence time. The exposure duration of each age group is the number of years defined by the age group. Thus, the exposure durations for the young child and the older child are 6 and 11 years, respectively. The exposure duration for the adult is 26 years minus the total duration of the child. In the case of the shoreline and water recreation scenarios, the adult duration is 9 years (26 years minus 17 years). For the recreational fishing scenario, the exposure duration for the adult is 15 years (26 years minus 11 years).

4.2.3.4 Averaging Time (AT)

The calculation of the averaging time depends on whether a cancer or noncancer assessment is conducted. For noncancer, the averaging time equals the exposure duration (e.g., for an exposure duration of 6 years for a young child, the averaging time is 2,190 days). For carcinogens, the averaging time is equal to a 70-year lifetime (i.e., 25,550 days) (USEPA 2014).

4.2.3.5 Exposure Point Concentrations (EPCs)

An EPC is the representative concentration of a chemical in an exposure medium that is used, in conjunction with other exposure parameters, to estimate the hypothetical risk in a human health risk assessment. An EPC is a conservative estimate of the average chemical concentration in a medium that a receptor is assumed to contact over time (USEPA 1989).

EPA specifies that the EPC represents a reasonable maximum exposure (RME) concentration for risk assessments. This is typically the 95th percentile upper confidence limit (95UCL) of the arithmetic mean and is calculated using EPA's ProUCL software (version 5.1.02; Singh and Singh 2015). The 95UCL represents the upper bound on the mean values, and therefore minimizes the potential that the selected EPC would underestimate the mean chemical concentration and corresponding exposure. ProUCL version 5.1 is the most current version (updated June 2016).[5]

Table 4-2 presents the summary statistics and ProUCL output for the total PCBs concentrations in surface water and surface sediments for the Spokane River. The summary statistics include

[5] https://www.epa.gov/land-research/proucl-software

the frequency of detection, arithmetic mean, range of detected results, and range of non-detect results. The arithmetic mean concentrations were calculated using one-half the reported detection limits for the non-detect results. The ProUCL output includes the distribution type, Kaplan-Meier mean (KM mean) concentration, 95UCL, and 95UCL type. Additional information regarding the surface water and sediment EPC calculations is presented below.

Surface Water Concentrations

I relied on surface water samples that were collected from the Spokane River in 2003 and 2012 through 2017. These data are most representative of current conditions. Surface water samples that were analyzed for PCB congeners represent a total of 143 sample results, including 18 field duplicates. A total of 150 to 189 PCB congeners or congener groups were analyzed in these samples. Total PCBs were calculated by summing the detected congener results on a sample-specific basis. Sample-duplicate pairs were averaged before calculating the EPCs.

Sample-specific results are provided in Appendix B, Table B-3a, and are summarized in Table 4-2a. Total PCBs were detected in 122 of the 125 (detection frequency of approximately 98 percent) surface water samples on a river-wide basis, with a range of detected results from 0.000130 to 0.000434 ppb. I selected a river-wide 95UCL surface water EPC of 0.000156 ppb, as recommended by EPA ProUCL software. Table 4-2a also shows the summary statistics for the four river reaches, including Post Falls Dam to Upriver Dam, Upriver Dam to Nine Mile Dam, Nine Mile Dam to Long Lake Dam, and Long Lake Dam to Lake Roosevelt, ordered from upstream to downstream. The corresponding 95UCL values are 0.000144, 0.000209, 0.000203, and 0.000026 ppb, respectively. I used both the river-wide and reach-specific surface water EPCs for my assessment.

Surface Sediment Concentrations

I focused my assessment on surface sediment, defined as all depth intervals starting from the top of the sediment to a maximum sediment depth of 0.5 ft (15 cm). I considered this depth interval to be a representative estimate of the depth of sediment that hypothetically might be contacted during recreational activities.

For the assessment of surface sediment contact, it is important to determine whether the samples were collected from water column depths where contact with sediment could occur. Although EPA does not have a standard wading depth, its general recommendation is to use sediment from water column depths where individuals have the potential for contact rather than deeper water column depths where any sediment is likely to be washed off before the individual reaches the shore (USEPA 2004b). For my review of the data, I defined wading depth as water column depth to a maximum of 3 ft (i.e., approximately waist deep). I attempted to plot the sediment sampling locations as an overlay on the bathymetry maps to determine which samples fall within this wading depth. However, bathymetry data were

available only for the Spokane Arm of Lake Roosevelt[6] and limited areas in the river (e.g., Upriver Dam remediation area). In order to provide an adequate number of sample results for my analysis, I assumed contact could occur with surface sediment regardless of the water column depth.

In line with the surface water data, I relied on sediment samples collected in 2003, 2004 and 2013. These data are most representative of current conditions. Total PCBs concentrations were calculated as the sum of the reported Aroclor PCBs or the sum of the reported PCB congeners for sediments. The sample-specific surface sediment results across sample years are provided in Appendix B, Table B-3b, and are summarized in Table 4-2b. Total PCBs were detected in 48 of the 61 surface sediment samples (detection frequency of approximately 79 percent) on a river-wide basis, with a range of detected results from 1.90 to 330 ppb_{dw}. I selected a river-wide 95UCL sediment EPC of 32.5 ppb, as recommended by EPA ProUCL software. Table 4-2b also shows the summary statistics for the four river reaches, including Post Falls Dam to Upriver Dam, Upriver Dam to Nine Mile Dam, Nine Mile Dam to Long Lake Dam, and Long Lake Dam to Lake Roosevelt, ordered from upstream to downstream. The corresponding 95UCL values are 36.0, 47.4, 42.0, and 10.4 ppb, respectively.

4.2.4 Scenario-Specific Parameters for Direct Contact Exposure Routes

There are a number of exposure parameters that vary depending upon the exposure scenario that is being evaluated. These include surface water ingestion rates, the skin surface areas that are in contact with the sediment or surface water, the amount of sediment that adheres to the skin after contact, the permeability of the skin to PCBs in sediments and surface water, the fraction of total daily exposure that involves impacted sediment or surface water, the exposure time, and the exposure frequency. Each of these is discussed below and summarized in Table 4-3.

4.2.4.1 Surface Water Ingestion Rate (IR_{sw})

USEPA (2019a, Table 3-7) provides average and upper-bound estimates of surface water ingestion rates that might occur during swimming for adults and for age groups of 6 to <11, 11 to <16, and 16 to <21 years. The average and upper-bound estimates for the 6 to <11 year old age group are 38 and 96 mL/hour, respectively. For the 11 to <16 year old age group, the average and upper-bound estimates are 44 and 152 mL/hour, respectively, and for the remaining group, the estimates are 33 and 105 mL/hour, respectively. For adults, the average and upper-bound estimates are 28 and 92 mL/hour, respectively. Although USEPA (2011) recommends using the average rates for exposure scenarios involving swimming, as a conservative and hypothetical approach, I assumed that individuals ingest surface water at the

[6] This is an older dataset (1940s) and is available from this URL: https://www.ngdc.noaa.gov/nos/H06001-H08000/H07700.html

upper-bound rates during every swimming event. I selected the rates for 6 to <11 year olds as those for the young child, and the rates for 11 to <16 year olds as those for the older child. Thus, I assumed surface water ingestion rates of 96, 152, and 92 mL/hour for the young child, older child, and adult shoreline recreator, respectively.

USEPA (2019a, Table 3-96) provides surface water ingestion rates for a number of water recreation activities. For canoeing and kayaking, average and upper-bound estimates are given for kayaking/canoeing with no capsize; kayaking/canoeing with capsize; and kayaking/canoeing with all activities. Age-specific rates are not provided. Of all the water recreation activities presented, the upper-bound surface water ingestion rate for canoeing with capsize is the greatest. As a conservative estimate, I assumed the upper-bound rate for canoeing with capsize (19.9 mL/hour) for the surface water ingestion rate for young child, older child, and adult water recreator.

Surface water ingestion rates are time-dependent; the assumptions for time spent swimming and kayaking are provided in Section 4.2.4.8.

4.2.4.2 Skin Surface Area (SA)

The skin surface area describes the amount of exposed skin that may come into contact with sediment or surface water. I relied on the age-specific surface areas for individual body parts recommended by USEPA (2011). These surface areas for males and females, combined, for the head, trunk, arms, hands, legs, and feet are presented in Table 4-4. While USEPA (2011) does not provide estimates for forearms and lower legs, USEPA (2004b) recommends that those be estimated as 45 percent of the surface area of the arms and 40 percent of the surface area of the legs, respectively.

Not all exposure scenarios are the same in terms of the body parts that may be in contact with the exposure medium. For example, the portions of the body that would be expected to contact surface water while fishing are not the same as the portions of the body that would contact surface water while swimming. Thus, based on my professional judgment, I have developed estimates of age-, scenario-, and exposure medium-specific exposed skin surface areas. These are discussed in more detail below.

Contact with Sediment

While some sediment contact may occur during all types of water-based activities, the likelihood that certain portions of the body will have direct contact with sediment varies by age group and by scenario. For example, children who are playing along the shoreline are likely to have greater contact with sediment than are adults who are fishing from the shore. In addition, it is not likely that adults will have as much contact with sediment as children, even when engaged in the same activity.

For the shoreline recreation scenario, I conservatively assumed that the entire surface area of the arms, hands, legs, and feet of young and older children could be in contact with sediment during every exposure event. This assumes that these individuals are in bathing suits during every visit to the shoreline, and that they might cover all of their arms, hands, legs, and feet with sediment during play activities. The result of these assumptions is exposed skin surface areas of 3,848 cm^2 for young children and 7,994 cm^2 for older children. While adults may also be in bathing suits during visits to the shoreline, I assumed that it is less likely that their entire arms and legs would be in direct contact with sediment during each visit. Thus, for adults, I assumed that the hands, forearms, lower legs, and feet might have direct contact with sediment during the most intensive shoreline activities. This results in a total surface area of 5,936 cm^2.

For the water recreation scenario, I assumed that individuals would launch their kayak or canoe from the shore. In doing so, the hands, forearms, lower legs, and feet might have direct contact with the sediment. This results in a total surface area of 2,103, 4,267, and 5,936 cm^2 for the young child, older child, and adult, respectively.

For the recreational fishing scenario, I assumed that the hands and feet of the older child and adult might have direct contact with sediment while fishing from the shoreline. If these individuals waded into the water during the shoreline fishing activities, it is unlikely that they would wade deeper than their knees, and the surface water would tend to wash away sediment on lower legs and forearms so that there would be little to no adherence of sediments to those surfaces. These assumptions result in surface areas of 1,610 and 2,214 cm^2 for older children and adults, respectively, as shown in Table 4-4.

Contact with Surface Water

For the shoreline recreation scenario, which would include swimming, I assumed that the entire surface area of the body could be in contact with surface water. Thus, I used surface areas of 7,502, 14,502, and 19,771 cm^2 for the young child, older child, and adult, respectively (Table 4-4).

If individuals wade into the water during fishing events or when launching a kayak, it is possible that their hands, forearms, lower legs, and feet would be in contact with surface water during that time. As shown in Table 4-4, I assumed exposed skin surface areas for surface water contact during fishing or kayaking of 2,103, 4,267, and 5,936 cm^2 for younger children, older children, and adults, respectively.

4.2.4.3 Adherence Factor for Sediment (AF_{sed})

The adherence factor describes the mass of soil or sediment that adheres to the skin after contact. Adherence is influenced by the properties of the soil or sediment (e.g., sediment particle size and moisture content) and varies considerably on different parts of the body and with different activities (USEPA 2004b).

USEPA (2004b, 2011) provides body part-specific adherence factors for a number of activities including a variety of recreational exposures. While the majority of the data available relate to the adherence of soil to the skin, USEPA (2011) provides adherence data for sediment for children and adults engaged in activities along a tidal flat. Shoaf et al. (2005a) obtained sediment adherence data for adults during clam digging activities, and Shoaf et al. (2005b) obtained sediment adherence data for children playing in a tidal flat. While these data are most relevant for exposure scenarios involving activities at a coastal shoreline or tidal flat, I used them in this analysis because the data represent sediment loading rather than soil loading.

I developed age-specific adherence factors as shown in Tables 4-5 and 4-6 for children and adults, respectively. These adherence factors were estimated by selecting the recommended adherence factor for each exposed body part and then calculating a surface area-weighted adherence factor for all body parts assumed to be exposed in the scenario being evaluated.

For children involved in shoreline recreation, for whom the hands, arms, legs, and feet could contact sediment, the adherence factors for those body parts recommended by Shoaf et al. (2005b) were used with one exception, the feet (21 mg/cm^2). Although a sediment layer may be very thick on the feet, it is only the inner-most layer of sediment that is actually in contact with the skin. Because PCBs adhere tightly to sediment particles and do not move easily in sediment, PCBs in the outer layers of sediment adhered to the feet will not be in contact with the skin or be available to be absorbed through it. Therefore, I applied an adherence factor of 1 mg/cm^2 as a conservative assumption and as most representative of the reservoir of PCBs in sediment that may be transferred through the skin of the feet. The Massachusetts Department of Environmental Protection (MADEP; 2002) also examined this question and reached the following conclusion:

> DEP believes that use of a sediment adherence factor of 22 mg/cm^2 is not reasonable as a default value because it may substantially overestimate the dose of contaminant received from dermal contact with sediment. Instead, DEP recommends using 1 mg/cm^2 as a default adherence factor for sediment. This value is the best estimate of the monolayer, which is in theory the level at which maximum absorption would occur.[7]

Because the sediment adherence data provided by Shoaf et al. (2005b) for children are not age-specific, I conservatively assumed that the sediment adherence factors for children were representative of potential exposures up through age 17. For the shoreline recreation scenario, I calculated adherence values of 0.57 and 0.58 mg/cm^2 for young children and older children, respectively (Table 4-5). For the water recreation scenario, I calculated adherence values of 0.61 and 0.62 mg/cm^2 for young children and older children, respectively (Table 4-5). For the

[7] MADEP developed this technical update prior to finalization of EPA's dermal guidance (USEPA 2004b) and thus refers to the value of 22 mg/cm^2 that was presented in the 1998 draft of that guidance. The number published in the final, 2004 version of that guidance (21 mg/cm^2) differed from the 1998 draft.

recreational fishing scenario, I calculated an adherence value of 0.79 mg/cm^2 for the older children (Table 4-5).

For adults, I based the sediment adherence factors on individuals who were engaged in clamming activities along a tidal flat (Shoaf et al. 2005a). These adherence factors were calculated as surface area-weighted averages assuming contact with hands, feet, lower legs, and forearms for the shoreline and water recreation scenarios, and hands and feet for the recreational fishing scenario. I calculated an adherence value of 0.36 mg/cm^2 for the adult for the shoreline and water recreation scenarios, and an adherence value of 0.71 mg/cm^2 for the recreational fishing scenario (Table 4-6).

4.2.4.4 Fractional Intake of Sediment That Is Impacted (FI_{sed})

Individuals may be exposed to soils and sediments from a number of locations during the day, including schools, offices, playgrounds, yards, and beaches. Thus, it is likely that at least a portion of the daily soil/sediment ingestion rate would be derived from areas outside of the Spokane River. However, as a conservative hypothetical assumption, I assumed that 100 percent of the soil/sediment contacted during each day of exposure was sediment from the Spokane River.

4.2.4.5 Oral and Dermal Absorption Factors (BA and ABS_d)

Oral and dermal absorption factors are used to adjust the hypothetical intakes to reflect the fractional amount of PCBs that are calculated as absorbed into the body. I conservatively assumed that 100 percent of the PCBs that are ingested in sediment and surface water are absorbed. Thus, a bioavailability adjustment (BA) of 1 has been used for the ingestion pathways.

In the case of skin contact, only a fraction of PCBs that contact the skin actually pass through the skin and are absorbed into the body. USEPA (2004b) recommends absorption factors for PCBs that are bound to soil or dissolved in surface water. Although there is no recommended value for sediment, I used the factor of 14 percent dermal absorption from soil to represent potential skin absorption (ABS_d) of PCBs for sediment (USEPA 2004b).

The permeability coefficient (K_p) is a measure of the absorption of chemicals from water through the skin. USEPA (2004b; Exhibit B-3) provides permeability coefficients for two PCBs: hexachlorobiphenyl and 4-chlorobiphenyl. Of these two PCBs, hexachlorobiphenyl is the most appropriate to use for surface water exposures because it more closely resembles the PCBs detected in the Spokane River surface water (i.e., the more chlorinated PCBs). Therefore, for dermal uptake from surface water, I used the K_p of 0.43 cm/hour based on hexachlorobiphenyl.

4.2.4.6 Event Frequency (EV)

Event frequency refers to the number of times per day an exposure event occurs on any exposure day. For dermal contact with sediment and surface water, I assumed the event frequency to be 1, per USEPA (2004b) guidance.

4.2.4.7 Exposure Frequency (EF)

The exposure frequency is the average number of days per year that an individual is assumed to participate in specific activities. While EPA guidance recommends exposure frequencies for residential and worker populations, it does not provide recommendations for recreational exposures. To determine the exposure frequency for recreational exposures, I relied on Sunding's (2019) estimates of the number of annual visits to the Spokane River for various recreational activities (Appendix C, Table 3). Mean and upper-bound estimates are reported. I relied on the upper-bound (95th percentile) exposure frequencies of 40, 21, and 10 visits per year for swimming, non-motorized boating (kayaking), and fishing, respectively.

4.2.4.8 Exposure Time (ET)

Because the surface water ingestion rate is time-dependent, it is necessary to make assumptions about the amount of time individuals might spend swimming or kayaking on each day of exposure. USEPA (2011) reports that the upper-bound estimate of time spent swimming by individuals who are 2 years of age and older is 181 minutes per month. Assuming that swimming occurs during 4 months of the year (June through September), I calculated an upper-bound estimate of total time swimming of 724 minutes over the year. When divided evenly over the exposure frequency of 40 days/year, I assumed an average daily exposure time of 18 minutes (0.3 hour). This exposure time was used for all three age groups for the shoreline recreation scenario. Recognizing that the average water temperature for the months of July through September in several areas within the river is only 60 degrees,[8] this exposure time is a conservative estimate.

For the water recreation scenario, full day paddles could occur, but more reasonable assumption would be half day or less trips. This is supported by kayak rental company offerings, which are typically for rentals of 1, 2, or 4 hours.[9] I assumed an exposure time of 4 hours/event for the water recreation scenario.

USEPA (2011) does not provide exposure time for fishing activity. Local and state fish consumption surveys often report frequency of fishing (i.e., number of fishing trips or days), but not the time spent fishing (hours per day). It is reasonable to assume a half day or even full day fishing trip when fishing by boat. When fishing from shore, it is unlikely that an angler

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[8] https://www.spokaneriverkeeper.org/riverjournal/2018/11/15/2018-spokane-river-water-temperature

[9] https://cdasports.com/spokane/kayak-rentals/

would fish from the same location along the shore for an extended period of time. However, as a conservative default value for the time spent fishing, I assumed a daily exposure time of 4 hours.

4.2.4.9 Fraction Absorbed (FA), Lag time per event (τ_{event})

The estimate of dermal absorption from surface water is dependent upon two chemical-specific factors, including the fraction absorbed (FA) and the lag time per event (τ_{event}). USEPA (2004b; Exhibit B-3) provides default values for these factors for two PCBs: hexachlorobiphenyl and 4-chlorobiphenyl. As previously discussed, hexachlorobiphenyl is the most appropriate to use for surface water exposures because it more closely resembles the PCBs detected in the Spokane River surface water (i.e., the more chlorinated PCBs). Thus, I used an FA of 0.5 and a τ_{event} of 11.29 per USEPA (2004b) guidance.

4.3 INGESTION OF FISH TISSUE

To evaluate potential exposures and risks due to the consumption of fish from the Spokane River on a river-wide basis (i.e., Idaho border to a portion of Lake Roosevelt), as well as for each river reach, I used more complete and in-depth EPA methods and conservative assumptions than the simpler approach used to evaluate the direct uses of the river. I performed a PRA for this evaluation. As previously stated, a PRA differs from the screening approach that I used to evaluate potential risks due to direct contact with sediment and surface water in that single values are not selected for each exposure parameter; instead, variations in behavior among individuals and over time are considered when estimating hypothetical exposures. This allows the full range of values for individual parameters to be incorporated in developing a probabilistic model of hypothetical risk. A distribution reflecting a range of values and the associated probability for each value within the range are incorporated for each input parameter rather than a single value. For example, there is a wide range of body weights among people, and the probability distribution for body weight is described as lognormal.

4.3.1 Exposure Equation for Ingestion of Fish Tissue

The equation for estimating hypothetical exposures in a probabilistic analysis is the same as the equation used for a more simplistic point estimate analysis, and is shown below:

$$I_{tissue} = \frac{C_{tissue} \times (1 - LOSS) \times IR_{tissue} \times RBA_{tissue} \times FI_{tissue} \times EF_{tissue} \times ED \times CF}{BW \times AT}$$

Where:

I_{tissue}	=	intake, the mass of a chemical contacted in fish tissue by the receptor per unit body weight per unit time (mg/kg-day)
C_{tissue}	=	chemical concentration in fish tissue contacted over the exposure period (i.e., EPC for fish) (mg/kg, or ppm)
LOSS	=	chemical reduction due to preparation and cooking (percent as fraction)
IR_{tissue}	=	fish ingestion rate (g/day)
RBA_{tissue}	=	relative bioavailability adjustment for fish tissue (percent as fraction)
FI_{tissue}	=	fraction of total fish intake that is site-related (percent as fraction)
EF_{tissue}	=	exposure frequency for fish consumption (days/year)
ED_{tissue}	=	exposure duration for fish consumption (years)
CF	=	conversion factor ($1{\times}10^{-3}$ kg/g)

In the PRA, I combined input parameter distributions in repeated calculations, using the above equation, to ensure that the full range of parameter values is incorporated into the assessment. Typically, ten thousand simulations (iterations) of the PRA are run, resulting in an output probability distribution across the range of exposure estimates. The output distribution provides hypothetical exposure estimates for given percentiles of the potentially exposed population at each exposure level. For this evaluation, I completed the probabilistic analysis using Oracle® Crystal Ball software (version 13.3), which employs Monte Carlo analysis, a commonly used and EPA-accepted probabilistic numerical technique.

To evaluate the fish consumption pathway, I conducted a 1-dimensional probabilistic analysis to focus on exposure variability. Exposure factors within the population reflect an inherent natural variation, resulting in a wide range of fish ingestion rates, exposure durations, and body weights. Exposure and toxicological factors can also be uncertain because of a lack of knowledge or due to limited information available about a specific parameter. While uncertainty can be reduced through further study, measurements, etc., variability cannot, and that is why it was the focus of the PRA. I addressed uncertainty in this 1-dimensional PRA through the use of conservative assumptions to account for limitations in or lack of perfect knowledge, particularly in the realm of toxicological factors. By design, most of this uncertainty is reflected in overestimated rather than underestimated risks.

Consistent with EPA's *Probabilistic Risk Assessment Guidance* (USEPA 2001), I adopted a tiered approach for this PRA. I began with a straightforward analysis to describe variability, without progressing into increasingly complex tiers of probabilistic analysis to quantify 1) changes in exposure over time; 2) uncertainty through the use of 2-dimensional PRA models (Price et al. 1996a); or 3) individual time-dependent exposures through the use of a microexposure event

model (Price et al. 1996b; Keenan et al. 1996). Such techniques are recognized in EPA's PRA policy and guidance (USEPA 1997; 2001).

4.3.2 Fish Ingestion Rate (IR_{tissue})

For the fish ingestion rate distribution for the adult angler in this PRA, I relied on Sunding's (2019) fish ingestion rate estimates (Table 4-7; Appendix C, Appendix Table 1). Specifically, I created an adult angler fish ingestion rate distribution based on the fish ingestion rate quantiles for Dr. Sunding's "residents who consume fish from the Spokane River," or the subset of the adult population living within the three Washington counties adjacent to the Spokane River that consumes fish from the Spokane River in a typical month.

Dr. Sunding used two data sources to understand patterns of angler behavior and fish consumption in the Spokane River area for his fish ingestion rate estimates. A 2015 survey conducted by Robinson Research (2015), and commissioned by the Spokane River Forum, was used to evaluate rates of recreational behaviors, including angling, and attitudes of users of the Spokane River. Fish consumption rates were estimated from a 2012 survey (IEc 2013) of recreational uses and fish consumption on the Upper Columbia River, including the Spokane Arm of Lake Roosevelt. This survey was conducted by IEc on behalf of the National Park Service and at the request of EPA. The IEc (2013) study included a greater number of respondents compared to Robinson Research (2015); therefore, Dr. Sunding's fish consumption rates calculated from IEc survey data are based on a more robust data set. Dr. Sunding's use of IEc survey data also assumes that rates of fish consumption are similar among anglers on the Spokane River and those from the Upper Columbia River within each demographic control group. Dr. Sunding additionally used responses from the IEc (2013) study to characterize other behaviors that impact individual exposure, such as sharing fish with children, awareness and responsiveness to advisories, and methods of fish preparation.

The plot that represents the shape of the fish ingestion rate input distribution for the adult angler is included as Figure 4-2.

IEc (2013) reported the percentage of adult anglers and fish consumers from its survey who typically share their catch with children but did not evaluate the fish consumption behaviors of children. Therefore, quantiles of fish ingestion rates for children were generated by Sunding (2019) based on the reported fish ingestion rates for adult "anglers who share with children"[10] and a child-to-adult fish consumption rate ratio of 0.3, to adjust for a child's smaller portion size, per studies conducted by NHANES. Use of the child-to-adult fish ingestion rate ratio of 0.3 generates conservative child fish ingestion rates, because it assumes that the anglers who

[10] The "anglers who share with children" subset of the surveyed adult population is different from the "residents who consume fish from the Spokane River" subset of the surveyed adult population. Data from the former were used to calculate young child angler fish ingestion rates, while fish ingestion rate data from the latter were used to represent the adult angler.

share fish with children share all of their fish meals with children. For the child angler in this PRA, I created a fish ingestion rate distribution based on Dr. Sunding's estimated quantiles of the fish ingestion rates for "anglers' children who consume fish" (Table 4-7; Appendix C, Appendix Table 5).

For each iteration of the probabilistic analysis, the modeling software selected a fish consumption rate at random from the appropriate adult and/or young child fish consumption rate probability distribution. The individual being modeled in that iteration is assumed to consume fish at the same rate throughout his or her multi-year exposure period.

4.3.3 Species Preference

For most fish consumers, it is likely that their total consumption includes a variety of different fish species and that they do not always consume the same species of fish at all fish meals. At the same time, there may be some individuals who eat only one or two species of fish. Therefore, it is necessary to develop species preferences that reflect the variations in fish consumption behaviors. I relied on Sunding's (2019) evaluation of species preferences from his assessment of the data provided in IEc (2013). The results of his analysis are presented below.

According to IEc's (2013) recreational consumption and resource use survey performed for visitors to the Upper Columbia River, which includes a portion of the Spokane River, the most popular fish species caught from the Upper Columbia River and kept for consumption are rainbow trout (average 3.3 fish meals per year), walleye (average 2.8 fish meals per year), bass (average 0.7 fish meals per year), and kokanee (average 0.6 fish meals per year). Consumption of other species was found to be relatively insignificant (altogether average 0.1 fish meals per year). The raw survey data from IEc (2013) were analyzed by Sunding (2019), who developed species preference percentages using the subset of IEc data for the three Washington counties adjacent to the Spokane River and adjusted based on the population demographics of the same area. In addition, Dr. Sunding recategorized the original species preferences into six species groups, including five species groups that are relevant to the available PRA fish tissue data (Section 4.3.4) and an "other" species group (Table 4-8; Appendix C, Appendix Table 3).

For this PRA, I used the species group-specific preference percentages reported in Sunding (2019), but I re-scaled the species preference values for each area of the river I evaluated (i.e., river-wide plus Lake Roosevelt, or each of the four river reaches) based on the fish tissue data available for that particular area. The resulting sets of species preference percentages, provided in Table 4-8, were used to calculate aggregate fish tissue concentrations (i.e., as EPCs), as described in further detail below.

4.3.4 Exposure Point Concentration in Tissue (C_{tissue})

This section summarizes the EPCs that I used for fish tissue. I relied only on fillet, skin-on results for my analysis for two reasons: 1) the majority of the analytical results are reported as fillet, skin-on, and 2) fish fillets are the most common fish preparation method (IEc 2013; WDOH 1997; SRHD 1998). Fish species were assigned to one of five species groups, including the trout, salmon, bass, walleye, or perch groups (heretofore identified as "PRA Gamefish Groups"), as follows:

- Brown trout—grouped under "Trout Group"
- Rainbow trout—grouped under "Trout Group"
- Mountain whitefish—grouped under "Salmon Group"
- Largemouth bass—grouped under "Bass Group"
- Smallmouth bass—grouped under "Bass Group"
- White crappie—grouped under "Bass Group"
- Walleye—grouped under "Walleye Group"
- Yellow perch—grouped under "Perch Group."

I excluded data for northern pikeminnow, carp, crappie, and other species that are not typically consumed (IEc 2013; Robinson Research 2015).

Some of the samples were collected as field duplicates. The results from the sample-duplicate pairs were combined using the following decision rules before summarizing and evaluating the results:

- If PCBs were detected in both the sample and duplicate, the average of the sample-duplicate pair was used as the combined sample result.
- If PCBs were detected in either the sample or duplicate but not both, then the detected result was used as the combined sample result.
- If PCBs were not detected in either the sample or duplicate, then the combined sample result was treated as a non-detect at the larger of the two non-detect results.

Ecology's Environmental Information System database contains 18 studies with Aroclor PCB data and 15 studies with PCB congener data for fish in the general area of the Spokane River. The data sources are listed and described in Appendix B, Table B-4a. Of these, I relied on four studies that reported Aroclor PCB results and three studies that reported PCB congener results. The remaining studies were excluded because they reported results for non-gamefish species or other tissue types, or were for other waterways. The studies that were retained represent samples collected in 2001, 2003, 2004, 2005, and 2012.

Total PCBs were calculated as the sum of the reported Aroclor PCBs or the sum of reported PCB congeners for fish (individual and composites). When sources reported both Aroclor PCB and PCB congener data for the same samples, I used the larger of the two results as the total PCBs concentration for those samples.

Total PCBs results were available for the trout group from all four reaches of the Spokane River and for Lake Roosevelt (Appendix B, Table B-4b). The other four PRA Gamefish Groups were not collected from all of the Spokane River reaches or from Lake Roosevelt. The majority of the PRA Gamefish Groups were collected from the Nine Mile Dam to Long Lake Dam and Long Lake Dam to Lake Roosevelt reaches.

The individual PRA Gamefish sample results that I relied upon for my analysis are provided in Appendix B, Table B-4c. Total PCBs were not detected in some of the PRA Gamefish samples (predominantly in some Perch Group and Trout Group samples).

I summarized the total PCB results as "river-wide plus Lake Roosevelt," defined as PRA Gamefish collected from the four reaches of the Spokane River in Washington State plus a portion of Lake Roosevelt as discussed in Section 4.1 and Appendix B. The river-wide plus Lake Roosevelt total PCBs data set for all PRA Gamefish consists of 122 data points with total PCBs detected in 111 of the samples (detection frequency of 91 percent) across all collection years from 2001 and later. The overall mean total PCBs concentration calculated using the EPA software ProUCL was 64.3 ppb (wet weight; ppb_{ww}). Summary statistics for all gamefish combined and for the individual PRA Groups are shown in Table 4-9 with additional detail provided in Appendix B, Table B-4d.

4.3.5 Cooking Loss (Loss)

It is well recognized that preparation and cooking may reduce chemical concentrations of lipophilic compounds in tissue (USEPA 2000b; Wilson et al. 1998). The amount of PCBs lost due to cooking can vary, depending upon the lipid content of the fish and the way in which the fish are prepared. I developed a distribution for chemical reduction of PCBs due to preparation and cooking based on a meta-analysis of cooking loss studies completed by AECOM (2012). AECOM (2012) identified studies with sufficient data for quantitative analysis of cooking loss for PCBs. Specifically, the analysis focused on studies that used a relevant and appropriate experimental method and presented changes in raw and cooked fish tissue PCB levels on a mass basis. The analysis was performed in this manner because a comparison of concentrations in raw and cooked fish alone neglects the change in tissue mass that occurs during cooking, which is often substantial. A total of 15 studies that met these criteria were identified. For all tissue types and cooking methods reported, these 15 studies yielded 79 data points for PCBs that were used in the quantitative evaluation. The study authors completed an outlier analysis and reported percentiles and statistics for cooking loss for PCBs both with and without outlier values (Table 4-10). The authors concluded that despite the variability, the available data are

sufficiently consistent and robust to support inclusion of a quantitative cooking loss factor in the assessment of exposure dose from consumption of fish (AECOM 2012).

I used the statistics presented by AECOM (2012) with outliers removed to develop the distribution for the cooking loss term for the PRA. I visually compared the cumulative frequency plot generated using data set percentiles to distribution-specific plots available in USEPA (2001, Appendix B) to select the most appropriate distribution fitting the given set of percentiles. The selected distribution type and percentile data were then incorporated into Crystal Ball to represent the total PCBs cooking loss parameter distribution. The resulting distribution ranged from 0 to 74 percent cooking loss with a median loss of 30 percent and a 90th percentile loss of 54 percent.

For each iteration of the probabilistic analysis, the cooking loss for PCBs was selected at random from the probability distribution of cooking loss factors. Once selected, this factor was used to adjust the PCB concentration selected for that iteration to reflect the concentration in the fish tissue that was consumed.

4.3.6 Fraction of Tissue Ingested from the Site (FI_{tissue})

Fish consumers may obtain their fish from a number of sources, including other recreational fisheries, purchases in a grocery store, restaurant meals, and gifts from friends. As a result, it is unlikely that they obtain all of their fish from a single waterbody throughout their exposure period. To model this variation in source of fish, a distribution for FI_{tissue} may be developed. However, for the Spokane River angler modeled in this PRA, I evaluated the angler's fish consumption behaviors using consumption rates specifically of fish from the Upper Columbia River; in the IEc (2013) study, participants were asked for the number and size of fish caught from the Upper Columbia River that they typically eat. By definition, since the consumption rate distributions were modeled based on a survey of site anglers, and fish consumption rates were assumed to be similar among anglers on the Spokane River and those surveyed, I assumed a FI_{tissue} of 1.0.

4.3.7 Relative Bioavailability Adjustment (RBA_{tissue})

Relative bioavailability adjustment (RBA) factors for oral pathways are used to account for the differences in chemical bioavailability in specific exposure media (i.e., soil, sediment, tissue) compared to the dosing vehicle used in the critical toxicity study that provides the basis for the toxicity criteria selected for use in the risk assessment. As a conservative factor, I assumed that 100 percent of the PCBs that are ingested as a result of the consumption of fish tissue are absorbed. Thus, a point estimate value of 100 percent or a factor of 1.0 was used as the relative bioavailability adjustment for fish tissue.

4.3.8 Exposure Frequency (EF_{tissue})

Long-term fish ingestion rates are calculated as annualized average daily rates of consumption. Thus, for example, if an individual eats ten, 8-oz (227-g) meals of fish in a year, his or her total consumption is 2,270 g/year. Dividing by 365 days/year yields an annualized average daily consumption rate of 6.2 g/day. Because rates are derived in this manner, it is necessary to use an exposure frequency of 365 days/year when estimating exposures to fish consumers. This value for EF_{tissue} was used as a point estimate in the PRA as it is not possible to vary it, given the basis for the ingestion rates themselves.

4.3.9 Exposure Duration (ED)

In 1998, a survey of fish license holders living in Spokane County was performed to evaluate patterns of fish consumption from the Spokane River (SRHD 1998). Respondents of this fish consumption survey reported on how many years they have fished the Spokane River. These data were used to create a lognormal distribution for the adult angler exposure duration. This distribution was based on a mean of 13.51 years, a 50th percentile of 10.0 years, a minimum value of 0 years, and a maximum value of 80 years. I used this distribution as the adult angler exposure duration for both the cancer and noncancer evaluations.

The exposure duration for the child angler, determined based on professional judgement, was a uniform distribution with a minimum of 1 year and a maximum of 6 years.

4.3.10 Body Weight (BW)

For the adult angler, in lieu of using discrete body weight values provided in USEPA (2014), I used the lognormal distribution of adult body weights, with a mean of 79.96 kg and a standard deviation of 20.73 kg, developed by Portier et al. (2007). This distribution is based on NHANES IV data for ages 18 to 65 years (Portier et al. 2007). The distribution for body weight was bound at the lower end at 30 kg and at the upper end at 180 kg as estimates of body weights below or above which it is "highly unlikely that an American adult will weigh" (USEPA 2001).

To model a child's body weight, I used a lognormal distribution with a mean of 17.27 kg and a standard deviation of 4.97 kg. This distribution is also based on NHANES IV data but for ages 1 to 6 years (Portier et al. 2007). The lower and upper bounds of the distribution, 4.4 and 52.4 kg, respectively, were based on lower and upper percentile weights available in USEPA (2011).

4.3.11 Averaging Time for Cancer (AT_c) and Noncancer (AT_{nc})

The averaging time is the time over which the total exposure is averaged to derive an average daily dose. For evaluating potential carcinogenic risks, the averaging time (AT_c) is always a "lifetime." USEPA (2014) recommends that the average length of a lifetime for men and women combined is 70 years. This equates to 25,550 days. I used this as a point estimate to calculate the average daily carcinogenic dose level, with the exception of when the exposure duration was greater than 70 years. Because the maximum value from the exposure duration distribution exceeds the average lifetime, the averaging time was set to equal the exposure duration when the exposure duration was greater than 70 years, so that the exposure duration was never greater than the averaging time.

For evaluating noncancer effects, the averaging time is equivalent to the exposure duration. Thus, if an individual is exposed for 30 years, the averaging time is also 30 years or the equivalent 10,950 days. For each iteration of the probabilistic analysis, the AT_{nc} was calculated by multiplying the number of years selected for the exposure duration for that iteration by 365 days/year to derive the noncancer averaging time.

4.4 HYPOTHETICAL CANCER AND NONCANCER RISKS

Once exposures have been estimated, the exposure estimates are combined with toxicological criteria to estimate the potential cancer risk or noncancer risk associated with those exposures. To estimate potential cancer risks, the intake for each pathway is multiplied by the CSF to estimate a total cancer risk. Total cancer risk is the increased probability that someone may experience cancer during his or her lifetime, above the background cancer rate in the U.S. population. Currently, the lifetime probability of a male resident of the United States developing cancer is 41 percent, which is equivalent to 410,000 cases per one million individuals or a probability of 0.41 (ACS 2017). The lifetime probability of a female resident of the U.S. developing cancer is 38 percent, or a probability of 0.38 (ACS 2017). Generally, EPA considers risks to be *de minimis* or below levels of concern if a source- or site-related increased probability of developing cancer is less than one in one million ($<1\times10^{-6}$), which would result in an increase over background cancer rates from 41 or 38 percent to 41.0001 to 38.0001 percent for males and females, respectively. EPA's acceptable target risk range is between one in one million and one in ten thousand (1×10^{-6} to 1×10^{-4}), and is recognized by WDOH (WDOH 2007; McBride 2018). If incremental excess cancer risks exceed one in ten thousand, EPA considers that risk to be above the target risk range and subject to action intended to reduce risks.

Excess incremental lifetime cancer risks are calculated as the product of the estimated lifetime average daily exposure (i.e., LADD) and the CSF using the following equation:

$$Cancer\ Risk(unitless) = LADD \times CSF$$

Where:

LADD	=	lifetime average daily dose of PCBs via the specified exposure route (mg/kg-day)
CSF	=	cancer slope factor $(mg/kg\text{-}day)^{-1}$.

I used EPA's CSF for highly chlorinated PCBs of 2 $(mg/kg\text{-}day)^{-1}$ to estimate the upper-bound cancer risks associated with total PCBs in Spokane River sediments, dermal contact with surface water, and ingestion of fish (USEPA 2017b). For ingestion of surface water, I used the upper bound CSF of 0.4 $(mg/kg\text{-}day)^{-1}$ (USEPA 2017b).

To evaluate noncancer risks, the ratio of the exposure term (i.e., average daily dose or ADD) to the corresponding RfD is calculated. The hazard quotient (HQ) is calculated for each exposure route using the following equation:

$$HQ(unitless) = \frac{ADD}{RfD}$$

Where:

ADD	=	average daily dose of the chemical via the specified exposure route (mg/kg-day)
RfD	=	reference dose (mg/kg-day).

To evaluate the effect of exposure via multiple exposure routes for each receptor, the route-specific HQs are summed to determine a noncancer hazard index (HI) using the following formula:

$$HI(unitless) = HQ_1 + HQ_2 + \ldots + HQ_i$$

Where:

HI	=	hazard index
HQ	=	hazard quotient for a specified exposure route (unitless).

If the resulting HI is less than 1 for a given hypothetical exposure scenario, then no adverse health effects are expected to occur (USEPA 1989). If the HI is greater than 1, then further risk

evaluation may be appropriate. However, HIs greater than 1 do not necessarily mean that any actual adverse health effects would be observed in a receptor population under the hypothetical exposure scenario that provides the basis for the exposure estimate. A substantial margin of safety has been incorporated into the RfD. Thus, adverse health effects may not occur even if the HI is much larger than 1. The ratio is not a measure of probability that adverse health effects will occur. That is, the level of concern for health effects to occur does not increase linearly as the RfD is approached or exceeded (USEPA 1989; Price et al. 1997; Swartout et al. 1998).

I used EPA's chronic oral RfD of 2×10^{-5} mg/kg-day (20 ng/kg-day) for Aroclor 1254 to evaluate potential noncancer risks due to contact with sediment and surface water, and for fish consumption for adults and older children. For the specific situation of evaluating subchronic exposures, which EPA defines as having an exposure duration of 7 years or less, I used EPA's subchronic oral RfD of 5×10^{-5} mg/kg-day (50 ng/kg-day) for Aroclor 1254 (USEPA 1994). Thus, I used the subchronic RfD to evaluate potential noncancer risks for young children.

4.4.1 Hypothetical Cancer Risks for Direct Contact with Sediment and Surface Water

Hypothetical cancer risks associated with direct contact with sediments and surface water combined are *de minimis* and well below EPA's target risk range of 1×10^{-4} to 1×10^{-6} and Ecology's acceptable risk level for establishing site cleanup levels of 1×10^{-5}. This is true for the shoreline recreation, water recreation, and recreational fishing scenarios, and true for the river-wide evaluation and for each reach-specific evaluation. The cancer risks for direct contact with sediment and surface water that are discussed below are for the river-wide evaluation. These results and the cancer risks for each reach-specific evaluation for the shoreline recreation, water recreation, and recreational fishing scenarios are presented in Tables 4-11, 4-12, and 4-13, respectively.

For the shoreline recreation scenario, I estimated a hypothetical total lifetime cancer risk, river-wide, for all age groups combined of 4×10^{-8}, with the largest portion coming from dermal contact with sediment (3×10^{-8}) and the lowest fraction coming from incidental ingestion of surface water (2×10^{-12}). Ingestion of sediment and dermal contact with surface water contribute risk levels of 1×10^{-8} and 4×10^{-9}, respectively (Table 4-11).

For the water recreation scenario, I estimated a hypothetical total lifetime cancer risk, river-wide, for all age groups combined of 2×10^{-8}, with the largest portion coming from dermal contact with sediment (9×10^{-9}) and the lowest fraction coming from incidental ingestion of surface water (3×10^{-12}). Ingestion of sediment and dermal contact with surface water contribute risk levels of 5×10^{-9} and 2×10^{-9}, respectively (Table 4-12).

For the recreational fishing scenario, the hypothetical total lifetime cancer risk, river-wide, for older children and adults combined, is $4{\times}10^{-9}$. The hypothetical potential risk due to dermal contact with sediment is estimated at $2{\times}10^{-9}$, due to ingestion of sediment is $1{\times}10^{-9}$, and due to dermal contact with surface water is $1{\times}10^{-9}$ (Table 4-13).

4.4.2 Hypothetical Noncancer Risks for Direct Contact with Sediment and Surface Water

For hypothetical noncancer risks, the calculated HQs and HIs associated with direct contact with sediments and surface water combined are *de minimis* and well below the benchmark of 1 established by both EPA and Washington. This is true for the shoreline recreation, water recreation, and recreational fishing scenarios, for the river-wide evaluation and for each reach-specific evaluation. Noncancer risks for direct contact with sediment and surface water discussed below are for the river-wide evaluation. These results and noncancer risks for the reach-specific evaluation for the shoreline recreation, water recreation, and recreational fishing scenarios are presented in Tables 4-14, 4-15, and 4-16, respectively.

For the shoreline recreation scenario, I estimated total HIs of 0.002, 0.003, and 0.001 for the young child, older child, and adult, respectively. I estimated for the young child, HQs of 0.0008 and 0.001 for ingestion and dermal contact with sediment, and HQs of 0.0000005 and 0.0001 for incidental ingestion and dermal contact with surface water. Ingestion and dermal contact with sediment resulted in calculated HQs of 0.0002 and 0.0007 for adults, and hypothetical HQs of 0.0004 and 0.002 for the older child. I estimated HQs of 0.0002 and 0.0003 for dermal contact with surface water for the adult and older child, respectively. I estimated HQs of 0.0000003 and 0.0000008 for incidental ingestion of surface water for the adult and older child, respectively (Table 4-14).

For the water recreation scenario, I estimated total HIs of 0.0008, 0.001, and 0.0006 for the young child, older child, and adult, respectively. I estimated for the young child, HQs of 0.0004 and 0.0004 for ingestion and dermal contact with sediment, while HQs of 0.0001 and 0.0000008 were estimated for dermal contact and incidental ingestion with surface water. Ingestion and dermal contact with sediment resulted in calculated HQs of 0.0001 and 0.0003 for adults, while ingestion and dermal contact with sediment resulted in hypothetical HQs of 0.0002 and 0.0007 for the older child. I estimated HQs of 0.0001 and 0.0002 for dermal contact with surface water for the adult and older child, respectively. I estimated HQs of 0.0000004 and 0.0000007 for incidental ingestion of surface water for the adult and older child, respectively (Table 4-15).

For the recreational fishing scenario, I estimated a total HI of 0.0003 for the older child and 0.0002 for the adult. The ingestion of sediment resulted in hypothetical HQs of 0.00006 and 0.0001 for adult and older child, respectively. Dermal contact with sediment resulted in calculated HQs of 0.0001 for adult, and 0.0002 for the older child. Dermal contact with surface

water resulted in an HQ of 0.00006 for adults and an HQ of 0.00007 for older children (Table 4-16).

In addition to the *de minimis* cancer and noncancer risks associated with direct contact to surface water and sediment, the concentrations of PCBs in the surface water are well below federal standards. Maximum contaminant levels (MCLs) are standards set by EPA for drinking water quality. The MCL is the threshold limit on the amount of a substance that is allowed in public water systems under the Safe Drinking Water Act. The MCL for PCBs is 0.0005 ppm.[11] The river-wide surface water EPC is 0.000000156 ppm and the maximum reported surface water concentration is 0.000000434 ppm. These concentrations are far below the MCL.

4.4.3 Hypothetical Cancer and Noncancer Risks Associated with Fish Consumption

USEPA (2001) PRA guidance indicates that risk managers may select an upper-bound estimate of risk from the high-end range of percentiles. It is generally recommended that the 95th percentile be used as a starting point for specifying high-end risks, but EPA indicates that risk managers may consider multiple factors when selecting the percentile to be used in estimating upper-bound risks. These factors include understanding the variability and uncertainty that are already taken into consideration in the PRA and the inputs that are used to derive the risk distribution. Risk managers may include both quantitative information and professional judgment. If adequate site-specific information has been collected to indicate that risk estimates are likely to be overestimated due to the inclusion of multiple, precautionary assumptions, a lower percentile may be selected as the most representative for the potentially exposed population. Sources of uncertainty that may be considered include the uncertainty in the exposure calculations, the uncertainty in the toxicity values, and the presence of measured data.

The extreme percentiles of an input distribution are understandably the most uncertain because the numbers of data points available in these extreme percentiles are far more limited than those in the center of the range of values. This results in greater uncertainty in the upper and lower percentiles of the calculated exposure and risk distributions, with the uncertainty substantially increased at the highest and lowest percentiles.

Based on the uncertainties associated with this analysis (discussed below) and the efforts made to ensure that the risks are not being underestimated, the 90th percentile was selected as the most representative estimate of hypothetical upper-bound risks for the potentially exposed population. However, in keeping with EPA policy recommendations, I have also reported the 95th percentile upper-bound hypothetical risk estimates. Thus, the median, arithmetic mean,

[11] https://www.epa.gov/ground-water-and-drinking-water/national-primary-drinking-water-regulations#Organic

90th percentile, and 95th percentile risks are reported to represent estimates of hypothetical central tendency and upper-bound risks to anglers.

Summary statistics for the hypothetical cancer and noncancer risks for site anglers, based on the PRA results, are shown in Table 4-17. The hypothetical lifetime cancer risk for all gamefish, river-wide plus Lake Roosevelt, has an arithmetic mean of 9×10^{-7} with a 90th percentile of 2×10^{-6}. These hypothetical cancer risks are within the target risk range established by EPA, recognized by WDOH (WDOH 2007; McBride 2018), and below the target cancer risk of 1×10^{-5} recognized by Ecology.

The hypothetical noncancer hazard distribution for the adult-only receptor exposed to all gamefish, river-wide plus Lake Roosevelt, has an arithmetic mean HI of 0.09 with a 90th percentile HI of 0.2. The hypothetical noncancer hazard distribution for the child-only receptor exposed to all gamefish, river-wide plus Lake Roosevelt, has an arithmetic mean HI of 0.1 with a 90th percentile HI of 0.2. These hypothetical noncancer hazards are below the target HI of 1 used by both EPA and Ecology for both adult and child receptors.

Summary statistics for river reach-specific hypothetical cancer and noncancer risks for all gamefish are also presented in Table 4-17. All central tendency (mean, median) and upper (90th) percentile estimates of hypothetical lifetime cancer risks are within the target risk range established by EPA and below the target cancer risk of 1×10^{-5} used by Ecology. All central tendency (mean, median) and upper (90th) percentile estimates of hypothetical noncancer risks are below the target HI of 1 used by both EPA and Ecology for both adult and child receptors.

4.5 CONSERVATISM IN THE RISK ASSESSMENT

Even though the results of the sediment and surface water risk assessment demonstrate that PCBs present in the Spokane River pose no threat to human health, it is still important to emphasize the conservative and precautionary nature of the assessment. The deterministic risk assessment was developed using a combination of upper-bound and central tendency exposure parameters and assumptions. However, in an effort to ensure that risks were not underestimated, a number of very conservative assumptions and approaches were taken for the risk evaluation. These include the following:

- Use of conservative exposure assumptions
- Compounding conservatism of exposure assumptions
- Combining sediment results across locations
- Conservative assumptions in toxicity benchmarks.

These are discussed below.

4.5.1 Conservatism in Exposure Assumptions Used in the Sediment and Surface Water Risk Assessment

I assumed that individuals engage in high intensity activities along the shoreline 40 days/year, that they wear bathing suits on all of those occasions, and that all or most of the unclothed surface areas are in contact with sediment. This combination of high exposure frequency and exposed skin surface areas is unlikely to occur. It is more likely that visits to the shoreline would occur less frequently, and if an individuals did visit 40 days/year, they would likely be engaged in a variety of activities that would not require bathing suits; therefore, they would have less potential for contact with sediment and surface water due to wearing more clothing.

I also assumed that 100 percent of the daily soil/sediment intake was sediment from the Spokane River. The sediment ingestion rates used are based on daily ingestion rates for all soils. While they may be representative of total daily intake of soil and sediment, it is highly unlikely that 100 percent of the intake that occurs is totally derived from sediment contact. Individuals spend time in many locations during the day and over the course of a year, including school, work, the homes of friends, parks, etc., so that their total daily intake is likely to be from a combination of sources, of which the sediments of the Spokane River would only be a fraction. In addition, direct contact would be with sand, rather than sediment, during recreational activities that occur along the shoreline in beach areas, so that actual uptake of PCBs has been overestimated.

Furthermore, it is important to recognize that a number of the exposure parameters were developed for exposure to soil rather than sediment. Sediment exposures are less frequent and less intensive than are soil exposures. Whereas individuals might have daily exposure to soil in their yards, sediment exposures are more likely to occur on a less regular basis during seasonal activities such as swimming, boating, and fishing. In addition, because sediment contact is typically associated with water contact activities, such as swimming and boating, the action of the water tends to "wash" most of the sediments from the skin, reducing dermal contact and time for potential absorption through the skin.

When estimating exposures during swimming activities, I used upper-bound ingestion rates of surface water as a precautionary and conservative measure. The upper-bound rates of 152 and 92 mL/hour for older child and adult, respectively, are greater than the mean values of 44 and 28 mL/hour for older child and adult, respectively, that are recommended by USEPA (2019a). Use of the upper-bound surface water ingestion rates adds further overestimation of risks.

4.5.2 Compounding Conservatism by Combining Exposure Assumptions

It is important to note that when the various exposure parameters are considered together, substantially overestimated risks result. This is because the conservative factors are multiplied together when combined in the risk calculation. For example, if there are three factors that each

overestimate exposure by a factor of 5, when these three factors are combined, the result is an overestimation of exposure by a factor of 125. Thus, it is important that the levels of conservatism included in risk estimates be considered when evaluating hypothetical risks.

4.5.3 Combining Sediment Results across Locations

The total PCBs results used to develop the EPC for the sediment pathways were based on surface sediment (i.e., samples that fall within the interval of 0 to 15 cm) collected from the Spokane River regardless of the water depth. This was necessary due to the lack of adequate bathymetry data for the river and to ensure sufficient data for EPC calculations. It is likely that many of these sampling locations are not accessible from the shoreline or are from non-wadeable depths (Appendix B, Figure B-2). Individuals who are involved in shoreline activities have no opportunity to be exposed to sediments in deep water.

4.5.4 Conservatism in the Probabilistic Risk Assessment

There are a number of precautionary assumptions associated with the PRA that have been made to ensure that risks and hazards are not being underestimated. These include assumptions about species preferences, species-specific PCB concentrations, fish consumption rates, exposure duration, and toxicity values. Each of these areas of conservatism is discussed below.

The 1-dimensional PRA was set up so that each iteration of the model would incorporate a single calculated fish tissue EPC, which is based on a single fish tissue concentration for each of the five fish species groups. It would then be assumed that this EPC was the only fish tissue concentration the receptor was exposed to for the entire exposure duration (i.e., all fish meals contained the same concentration of PCBs), even when exposures lasted a lifetime of 80 years. In fact, it is most likely that individuals consume a varying distribution of fish species, each with variable concentrations, from the Spokane River within a given year and over a lifetime. Use of a 1-dimensional PRA approach limits the options for capturing the extent of this type of variability in behavior.

In addition, there is some evidence that the PCB concentrations in gamefish (e.g., rainbow trout and mountain whitefish) collected from the Spokane River have declined over time (Ecology 2011). Given that the fish concentration data incorporated into the PRA have likely decreased over time, concentrations used in this analysis are not likely to be representative of future concentrations to which people may be exposed. This, combined with the assumption of same-PCB concentration fish meals consumed during the entire exposure period, almost assuredly overestimates potential exposures. Development of a time-varying 2-dimensional microexposure event analysis would allow these variations in behavior and concentrations to be more accurately captured.

The use of one-half the reporting limit for Aroclor PCBs in those samples where PCBs were not reportable as the total PCBs concentration was required for a number of gamefish samples under the river-wide plus Lake Roosevelt scenario based on the Aroclor PCB analyses. Use of the one-half adjustment factor (or equivalently, dividing by 2) has been used historically as a simple approach for addressing non-detect results but likely yields a conservative (higher) estimate of the "true" detection limit in the affected samples.

It was assumed that exposures via consumption of fish from the Spokane River could continue for as long as 80 years. It is very unlikely that a single individual would catch and consume recreationally-caught fish from the river for that length of time. Instead, it is much more likely that individuals will only spend a portion of their lifetime living near the river and that there will be years during which they will not fish. Reduction of the exposure duration to a more reasonable maximum value would reduce the upper percentile risk estimates, shifting the distribution of risk results to lower estimates.

4.5.5 Conservative Assumptions in Toxicity Benchmarks

Finally, as discussed in Section 3, the toxicity values that I used are highly conservative. The upper-bound CSFs of 2 and 0.4 $(mg/kg\text{-}day)^{-1}$ were used to estimate hypothetical upper bound cancer risks due to sediment and surface water contact. However, had the central estimate CSFs been used instead, estimated cancer risks would have been reduced by as much as one-half. EPA recognizes that cancer potency may be overestimated using the CSF values that it has defined and may, in fact, be zero (USEPA 2004a). This is particularly important for PCBs, which have not been shown to be carcinogenic in humans.

Similarly, the RfDs used to evaluate potential hazards due to PCB exposure are highly conservative estimates that likely overstate toxic potential in humans, as discussed in Section 3.1 and subsections. In a report that he prepared for the U.S. Navy, Dr. DeGrandchamp expressed similar views:

> It should be stressed that the use of uncertainty and modifying factors represents risk policy and not necessarily science. That is, uncertainty is always addressed by introducing an *increasing* amount of conservatism without determining whether it is warranted or scientifically valid. (DeGrandchamp and Pyatt 2001 p. 21)

In deriving the RfD for Aroclor 1254, which was used to evaluate sediment exposures, EPA adjusted the LOAEL of 0.005 mg/kg-day by a combination of uncertainty factors that totaled 300 to derive the RfD of 2×10^{-5} mg/kg-day. It is likely that two of those uncertainty factors were unnecessary. A factor of 3 was used based on the assumption that humans are more sensitive to the toxic effects of PCBs than are monkeys, which were the subjects of the toxicity study upon which the RfD is based. There is substantial evidence to indicate, however, that this is not the case and that, in fact, monkeys are more sensitive to the toxic effects of PCBs than are humans.

Even Dr. DeGrandchamp has written "… if the laboratory species used in toxicological experiments was actually *more* sensitive to a chemical than humans … introducing uncertainty factors into the RfDi would be ultraconservative, since the unaltered NOAEL already represents a conservative estimate of the toxic potential of the chemical with respect to human exposures" (DeGrandchamp and Pyatt 2001). Also, an additional uncertainty factor of 3 was used to derive a chronic RfD based on a less-than-lifetime study in the monkeys. However, evidence indicates that the monkeys had achieved a steady-state body burden and clinical health effects of PCB exposure would not be expected to worsen once PCB equilibrium was achieved. When the UFs for interspecies extrapolation and for subchronic to chronic are reduced to 1, the RfD is increased by a factor of 10, thereby reducing noncancer risks by a factor of 10.

In addition, the PRA used point estimates in lieu of probability distributions to represent the potential carcinogenic and noncancer toxicity of PCBs. The point estimate toxicity values are based on the results of animal bioassay data and have been derived using a number of conservative assumptions and adjustment factors in an attempt to predict potential human responses. Because of the precautionary conservatism built into their derivation, it is virtually certain that the actual toxicity of PCBs to humans has been overestimated by these point estimates. More realism would be gained if probability distributions had been substituted for the point estimate toxicity values that were used in the PRA. Methods developed by EPA and other authors describe a framework for conducting such evaluations (Price et al. 1997; Swartout et al. 1998; USEPA 2009b). Had the range of toxicity values been incorporated as distributions, risk and hazard estimates would have been further reduced.

4.6 SUMMARY OF CONCLUSIONS

With respect to PCBs, the hypothetical risks of all common, real-world recreational uses of the Spokane River are well within the range of risks deemed acceptable by EPA and the State of Washington. The river is safe for all known uses, including intensive recreational activities such as swimming, wading, sunbathing, picnicking, kayaking, canoeing, rafting, and fishing, and for eating fish caught from the river.

The results of my site-specific PRA, performed to evaluate the consumption of fish from the Spokane River, show that hypothetical upper-bound incremental cancer risks for all gamefish, river-wide plus Lake Roosevelt, are no greater than 2×10^{-6}. This means, hypothetically, that the increased risk of an individual male angler developing cancer as a result of upper-bound consumption of Spokane River fish would be no greater than 41.0002 percent compared with his background cancer rate of 41 percent from all causes. Likewise, the increased risk of an individual female angler developing cancer as a result of upper-bound consumption of Spokane River fish would be no greater than 38.0002 percent compared with her background cancer rate of 38 percent.

5 RISK MANAGEMENT OF PCBs IN SPOKANE RIVER FISH

The previous sections of this report present a detailed discussion of my site-specific risk assessment that used conservative, EPA-approved risk assessment methods for evaluating the safety of the Spokane River. In light of that evaluation, I also examined the fish advisories that have been issued for the Spokane River.

Fish advisories are a one-size-fits-all preliminary screening risk calculation and are not equivalent to conducting a site-specific risk assessment. The advisories do not provide predictions of adverse impacts and do not constitute a "ban" of any sort, but rather simply provide the public with recommendations about fish consumption that can be used to reduce health risks, based on a conservative and generic approach.

In this section, I provide a summary and review of the existing fish advisories and evaluate whether the presence of PCBs limits the safe consumption of fish caught from the Spokane River, given more realistic estimates of fish consumption based on site-specific data. **Consistent with my PRA, when the consumption rates of locally caught fish, preferences for eating different fish species, and differences in fish preparation and cooking methods are considered, there are no unreasonable risks predicted for consumption of fish from the Spokane River**.

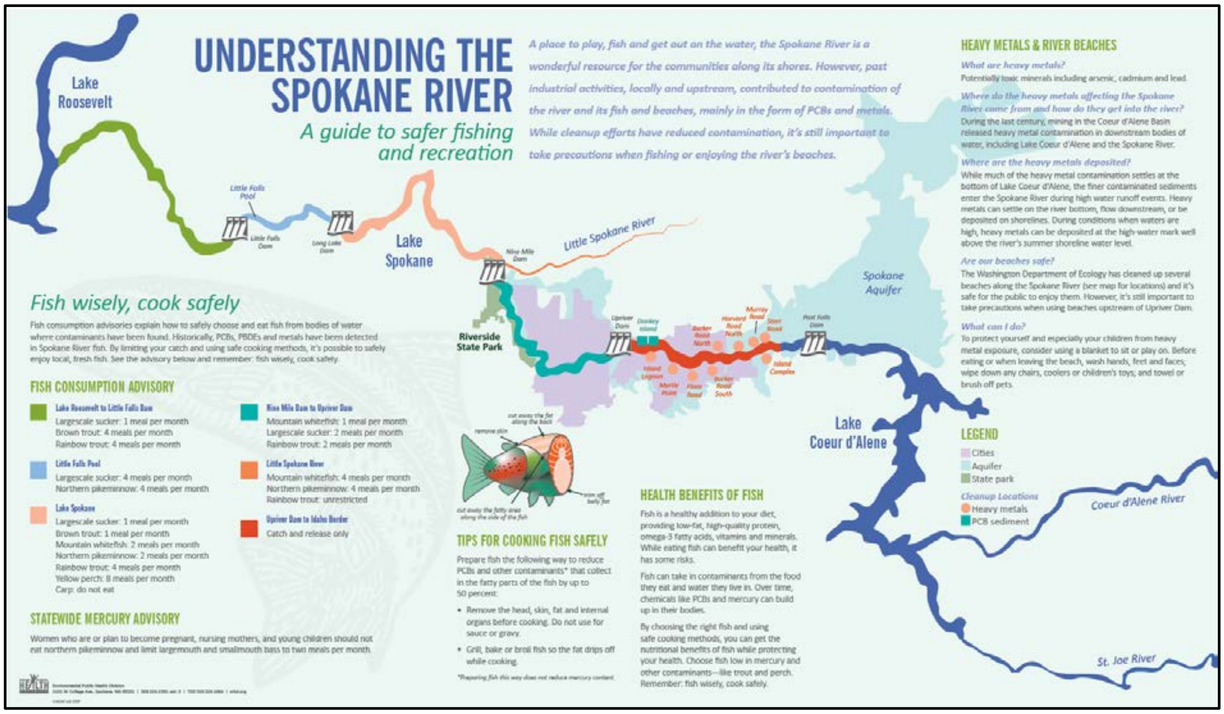
5.1 OVERVIEW OF WDOH FISH CONSUMPTION ADVISORIES

WDOH has issued fish consumption advisories for portions of the Spokane River since 1999, when an advisory was first issued for lead; advisories in 2001 and 2003 included additional metals and PCBs (WDOH 2007). In 2007, WDOH issued a report (WDOH 2007) that updated the consumption advice based on additional fish tissue data collected in 2005. Revisions were made to the 2007 advisory (provided in a poster/fact sheet format) in 2008 and 2009, in terms of the number of recommended meals and/or the definition of certain reaches of the river and the consumption advice for those reaches. WDOH (2007) also provides the agency's approach to assessing risk from fish consumption and methods for determining the recommended number of meals per month.

In 2019, an updated poster (Exhibit 5-1) was published by the Spokane Regional Health District (SRHD; 2019) with consumption advice that differed from previous poster versions. This most recent poster mirrors the consumption advice currently available on WDOH's website (WDOH 2019) and corresponds to information in a presentation by WDOH staff toxicologist Davis McBride (McBride 2018). For most species and reaches addressed previously, the 2018/2019 advisory increases the recommended number of meals per month. The 2018/2019 advisory is based on fish collected in 2012, which showed a decline in mean fish tissue total PCBs concentrations for gamefish species such as rainbow trout. For example, rainbow trout mean

total PCBs concentrations declined from 113 to 73 ppb$_{ww}$ between 2005 and 2012 for the Upriver Dam to Nine Mile Dam river reach.

Exhibit 5-1. Current Fish Consumption Advisory (SRHD 2019)



WDOH updated fish advisories across Washington State, including for the Spokane River in 2018 (McBride 2018), and the current poster in Exhibit 5-1 mirrors that updated advice. Assuming that the 2018/2019 advisory supersedes all previous advisories and evaluations published, it is potentially confusing to anglers that the 2009 poster with different meal recommendations still appears on the WDOH website.[12]

Fish tissue data from 2012, used in the 2018 assessment for PCBs (as Aroclors), PBDEs, and mercury, are available for five reaches of the Spokane River for five species: brown trout, largescale sucker, mountain whitefish, northern pikeminnow, and rainbow trout (Exhibit 5-2). Data are summarized as mean concentrations (wet weight), and the recommended number of meals per month is based on all three contaminants assessed (Exhibit 5-2). McBride (2018) also indicates that others factors were considered in the advisory, including health benefits of fish consumption, background or ambient levels, contaminants in other foods, risks posed by other foods, and contaminant reduction from preparation and cooking. The advisory was also simplified for ease of communication.

[12] The 2009 poster is available from this URL: https://www.doh.wa.gov/Portals/1/Documents/Pubs/334-164.pdf

The 2019 consumption advisory from the WDOH website is summarized in Table 5-1. There are some differences between the information available online through WDOH (Table 5-1) and that in Exhibit 5-2 (McBride 2018). For example, lead is noted in Table 5-1 as an additional contaminant driving the advisories for some species and reaches, but it was only detected in largescale suckers in the 2012. Also, there is a "do not eat" advisory for common carp in Long Lake, based on PCBs only (WDOH 2019).

For the river reach between the Idaho border and Upriver Dam, Exhibit 5-2 explains the "do not eat" designation in Table 5-1. There is a note in Exhibit 5-2 for that reach regarding the actions of the Washington Department of Fish and Wildlife (WDFW): "WDFW has closed this area—Catch and Release only." A similar catch and release designation is reported by the Silver Bow Fly Shop, a local fly fishing outfitter located in Spokane Valley: "As of Friday March 15th the Spokane River is closed for the season on the Washington side... the river is CLOSED…The reason for the closure on the Washington side is to protect the remaining Redband trout during their spawning season. These stretches will reopen the Saturday before Memorial Day, which is May 25th" (Silver Bow Fly Shop 2019).

This "do not eat" designation for the reach between the Idaho border and Upriver Dam is not based on PCB levels. Without this "ban" on catching fish between the Idaho border and Upriver Dam, the allowable number of meals per month would be two for sucker and four each for pikeminnow and trout (Exhibit 5-2). Thus, fish in this reach have similar, or in some cases lesser, restrictions than in other reaches. Fish would be safe to eat in this reach.

Two additional, statewide fish consumption advisories apply to the Spokane River. Both advisories are based on mercury contamination and are intended to protect women who are or may become pregnant, nursing mothers, and children. They cover three species of fish:

- Northern pikeminnow: do not eat
- Largemouth and smallmouth bass: limit to two meals per month (WDOH 2019).

Exhibit 5-2. 2018 Fish Consumption Assessment for the Spokane River (McBride 2018)

2018 Assessment – Cumulative Effects

Calculated Meal Limits Assuming 50% Reduction in Organics

Species	PCB sampling data		PBDE sampling data		Mercury sampling data		Combined	Recommendations*
	Mean PCB Aroclor Conc. (ug/kg ww)*	PCB Aroclor Meals/Month*	Mean PBDE Conc. (ug/kg ww)*	PBDE Meals/Month*	Mean Hg Conc. (ug/kg ww)	Hg Meals/Month	Meals/Month*	Recommendation for both PCBs, PBDEs, & Hg*
Spokane Arm								
Largescale sucker (whole)	113.8	1.6	123.3	6.5	60.3	13.3	1.4	1
Brown Trout (fillet)	33.3	5.6	30.4	26.5	85.4	9.4	3.6	4
Rainbow Trout (fillet)	28.8	6.5	8.5	94.7	49.6	16.2	5.2	4
RM 33.7 - Little Falls Pool								
Largescale sucker (whole)	33.0	5.7	20.4	39.5	39.0	20.6	4.8	4
Northern Pikeminnow (fillet)	25.9	7.3	8	100.6	147.0	5.5	3.3	4
RM 56.6-57.1 - Upper Lake Spokane								
Largescale sucker (whole)	126.0	1.5	102.6	7.8	55.3	14.5	1.4	1
Mt whitefish (fillet)	81.6	2.3	159.0	5.1	30.7	26.2	1.7	2
Northern Pikeminnow (fillet)	53	3.5	31.8	25.3	157.0	5.1	2.2	2
Rainbow Trout (fillet)	43	4.4	32.7	24.6	44.1	18.2	3.7	4
RM 64 & 77 - Nine Mile Dam to Up River Dam								
Largescale Sucker (whole)	63.0	3.0	64.1	12.6	25.0	32.2	2.7	2
Mt whitefish (fillet)	125.0	1.5	417.2	1.9	50.0	16.1	0.9	1
Rainbow Trout (fillet)	49.3	3.8	93.4	8.6	36.9	21.8	2.7	2
RM 84.4 & 96 - Upriver Dam to Border (Note: WDFW has closed this area - Catch and Release Only)								
Largescale Sucker (whole)	75.1	2.5	67.0	12.0	46.4	17.3	2.2	2
Northern Pikeminnow (fillet)	21.6	8.7	5.9	136.6	185.0	4.3	3.1	4
Rainbow Trout (fillet)	29.9	6.3	27.7	29.0	36.5	22.0	4.9	4

Notes:
"*" indicates that a 50 percent reduction in PCBs and PBDEs has been incorporated into meal recommendations based on EPA guidance that reports removal of skin and fat from fish can reduce contaminants in edible fish tissue by 50 percent.

5.2 APPROACH TO DEVELOPMENT OF FISH ADVISORIES

WDOH (2007) provides the following tables related to the development of fish advisories. Table C1 (Exhibit 5-3, below) shows the exposure assumptions for "deriving health-based comparison values" (based on cancer risk), and Table C2 (Exhibit 5-4, below) shows the assumptions used for calculating 8-oz fish meal limits (based on noncancer risk).

Exhibit 5-3. Exposure Assumptions for Deriving Health-Based Comparison Values (WDOH 2007)

Table C1. Exposure assumptions for deriving health-based comparison values

Parameter	Value	Unit	Comments
Concentration (C)	Variable	ug/kg	Maximum detected value.
Conversion Factor$_1$ (CF$_1$)	0.001	mg/ug	Converts contaminant concentration from micrograms (ug) to milligrams (mg)
Ingestion Rate (IR) – Subsistence	42 g/day	g/kg/day	Average recreational anglers (42 g/day) [48,49]
Conversion Factor$_2$ (CF$_1$)	0.001	mg/ug	Converts contaminant concentration from micrograms (ug) to milligrams (mg)
Conversion Factor$_2$ (CF$_2$)	0.001	kg/g	Converts mass of fish from grams (g) to kilograms (kg)
Exposure Frequency (EF)	365	days/year	Assumes daily exposure consistent with units of ingestion rate given in g/day
Exposure Duration (ED)	30 (adult) 5 (child)	years	Number of years eating fish
Averaging Time$_{non\text{-}cancer}$ (AT)	10950	days	30 years
Averaging Time$_{cancer}$ (AT)	25550	days	70 years
Oral Reference Dose (RfD)	Contaminant-specific	mg/kg/day	Source: ATSDR, EPA, IRIS
Cancer Risk	1x 10-5	unitless	Target Cancer Risk
Cancer Slope Factor (CSF)	Contaminant-specific	mg/kg-day-1	Source: EPA

Exhibit 5-4. Exposure Parameters for Calculating 8-oz Fish Meal Limits (WDOH 2007)

Table C2. Exposure parameters for calculating 8-ounce fish meal limits

Parameter	Value**	Units	Source
Reference dose	0.00002* for PCBs, BDE-47 (0.00023), BDE-99 (0.00013), BDE-153 (0.00015), BDE-209 (0.007)	mg/kg-day	EPA Iris [50] EPA draft [51]
Days per month	30.4	days per month	
Body weight	60 (adult pregnant women) and 70	kg	EPA exposure factors handbook
Concentration	Mean concentration specific to fish species	mg/kg	2005 Aroclor and PBDE data
Meal size	0.227	kg	Kg per 8 oz.

* RfD corresponds to Aroclor 1254

** Exposure parameters are defined in Table C1.

The WDOH (2007) study provides the 42 g/day fish consumption rate for use in calculating "comparison values," which equates to approximately 10 oz over a week (i.e., one 10-oz meal per week). Exhibit 5-4 specifies a meal size of 8 oz for setting advisories, or approximately 32 g/day if consuming one fish meal per week. There is no explanation for the difference in meal sizes, and "comparison values" are neither provided nor is their intended use explained.

The references provided for the 42 g/day fish ingestion rate include:

- A WDOH (1997) study surveying Lake Roosevelt anglers as they brought in their catch over several months in the summer/fall of 1994–1995. The main conclusions were:
  - "Surveyed individuals were primarily older adult Caucasian males that are part of two adult households in which both individuals consume fish. Results indicate that surveyed anglers consume an average of 42 meals per year, with greater than 90% consuming 103.2 meals (2 meals/week) or less per year."
  - Regarding fish meal size: "This indicates that the questions were not adequate for determining fish meal size, and that accuracy in response will only be enhanced through the use of standardized fish/fillet models."
- A SRHD (1998) study based on a survey mailed to a random sample of fishing license holders and members of the Walleye club. SRHD also had focus group surveys with the Russian and Laotian community. The main conclusions were:
  - "The respondents of this study seemed to be low consumers of the fish from the Spokane River (< 1 fish meal/week) as defined by the study prepared by ATSDR [Agency for Toxic Substances and Disease Registry]."
  - "Many of the respondents who kept fish from the river to eat, did not complete all sections of the survey…," which limits the analysis to the point of being inconclusive.

I could not replicate the derivation of the 42 g/day consumption rate from the information in the Lake Roosevelt study. The rate of 42 meals per year does not equate to an ingestion rate of 42 g/day. The Ecology (2013) fish consumption rate study provides a value of 26 g/day based on this source (WDOH 1997) but describes the tribal survey as follows: "DOH in cooperation with the Spokane Tribe, water body- and angler-specific creel survey; 42 fish meals/year; assuming 8-ounce meal. This is approximately 26 g/day." The most recent fish consumption advisory posters and fact sheets do not provide any indication of meal size, but it can be presumed to be 8 oz based on Table C2 (Exhibit 5-4) from WDOH (2007) and Ecology (2013).

5.3 SITE-SPECIFIC EVALUATION OF ALLOWABLE FISH TISSUE CONCENTRATIONS

Based on site-specific information concerning rates and fish species that people are actually eating from the Spokane River, I calculated hypothetical levels of PCBs in fish that would not exceed hypothetical risk levels. For this analysis, I used the overall approach from WDOH (2007), but incorporated site-specific fish ingestion rates and other parameters more fully described in the PRA, as described below, to develop a set of risk-based tissue concentrations for PCBs (i.e., based on the parameters provided in WDOH 2007, Tables C1 and C2). In Table 5-2, I present these estimated "fish tissue target" total PCBs values.

As discussed in Section 4.3.2, I relied upon Sunding's (2019) estimated mean, 90th percentile, and 95th percentile fish ingestion rates for the Spokane River child and adult angler evaluation in the PRA. These rates are significantly lower than the 32 g/day assumed by WDOH. In this section, I use these ingestion rates to estimate site-specific fish tissue target concentrations for the Spokane River (Table 5-2). Site-specific targets, which are based on site-specific fish consumption habits, are concentrations in fish tissue that would correspond to acceptable risks to the population of anglers consuming fish from the Spokane River. Based on Dr. Sunding's 95th percentile, 90th percentile, and mean consumption rates, the estimated site-specific targets are 136, 226, and 522 ppb_{ww} total PCBs, respectively. I also used the site-specific ingestion rates to define the frequencies of fish meal ingestion for Spokane River anglers. Based on Dr. Sunding's analysis, anglers would consume one 8-oz meal every 2, 4, or 7 weeks based on the 95th percentile, 90th percentile, and mean consumption rates, respectively (Table 5-2).

In Table 5-3, I provide the mean total PCBs concentrations in fish tissue for the fish species groups assessed in the PRA, as well as a species preference weighted mean, for each river area/reach.[13] The use of mean concentrations to develop fish consumption advisories is consistent with the approach used by WDOH. All fish tissue mean total PCBs concentrations, as well as the calculated species preference weighted mean total PCBs concentrations, are below the site-specific targets estimated using Dr. Sunding's mean and 90th percentile fish consumption rates. Only the salmon species group, which has a low species preference of 15 percent, in the Upriver Dam to Nine Mile Dam river reach has a mean total PCBs concentration that exceeds the target concentration estimated using Dr. Sunding's 95th percentile ingestion rate.[14] In other words, all other fish concentrations in Table 5-3 are below all of the Sunding-based targets. This finding is consistent with the results of the PRA.

[13] The species preference weighted mean is an aggregate fish tissue PCB concentration that I calculated by weighting the sum of the selected fish tissue concentrations based on their species preference fractions (Section 4.3.3).

[14] This exceedance is not indicative of an unacceptable noncancer risk. If a hypothetical angler was to eat only mountain whitefish, only from this reach of the river, and at the 95th percentile fish ingestion rate, then his or her hypothetical HI would equal 1.2. This value does not exceed the bounding range of uncertainty specified in the RfD definition (USEPA 2019b).

In summary, consistent with the PRA results, I have determined that, at the site-specific estimated rate of fish consumption in the Spokane River, current concentrations of PCBs in fish tissue do not pose an unacceptable risk for human consumption.

6 CRITIQUE OF RICHARD DeGRANDCHAMP'S OPINIONS

In this section, I include a review and critique of DeGrandchamp's (2019) discussions regarding Spokane River fish tissue PCB concentrations, fish advisories for the Spokane River, and his opinion of potential public health concerns from consuming Spokane River fish. This evaluation will show that Dr. DeGrandchamp's opinions are based on outdated information or interpretations that are not relevant to the current conditions of the river. Further, he did not perform a risk assessment to support his opinions, and his conclusions are speculative and unreliable.

My critique does not include an analysis of Dr. DeGrandchamp's opinions related to implementation of control measures proposed by the City of Spokane (which he broadly classified as "remedial activities"; see his opinions numbered 8, 9, and 10). These are addressed by others.

6.1 RELIANCE ON OLDER FISH PCB DATA MISREPRESENTS CURRENT CONDITIONS

Dr. DeGrandchamp did not perform an independent analysis of the fish tissue PCB data to form his opinions, but rather compiled and presented the results used and the interpretations of results performed by others. Furthermore, he did not use the results from the most recent fish collections (i.e., from 2012) to develop his opinions.

Dr. DeGrandchamp references the risk assessment results from WDOH (2011) as the basis for his conclusions. The WDOH study used the mean total PCBs concentrations calculated for fillets and whole body fish collected in 2005 only. The fillet results were based on a combination of fillet data for rainbow trout, mountain whitefish, and brown trout. I included fillet data for these three species for this collection year in my PRA. The whole body results cited by Dr. DeGrandchamp are based on a combination of largescale sucker and bridgelip sucker. Neither of these sucker species are identified as preferred gamefish species for consumption (Sunding 2019); therefore, I did not include these data in my PRA.

If Dr. DeGrandchamp had examined the underlying fish concentrations used in WDOH (2011), he would have observed that bias was introduced in WDOH's calculation of mean values. The sample-specific results used to develop the mean total PCBs concentrations were not provided in WDOH (2011); however, review of EIM Study ID DSER0016 shows that the fillet samples collected in August, September, and November 2005 consisted of 9 rainbow trout samples, 15 mountain whitefish samples, and 1 brown trout sample (Appendix B, Table B-4c). All were analyzed for Aroclor PCBs only. Instead of using all 25 of these available fillet sample results from 2005 to calculate a river-wide mean total PCBs concentration, WDOH first computed average total PCBs concentrations at each sample station for each fish species. It then calculated

a weighted average using only the maximum of the average total PCBs concentration for each of the fish species.

The calculation performed in WDOH (2011), along with the more realistic "river-wide" approach of combining species-specific results across all sampled areas, is summarized in Table 6-1. WDOH calculated a weighted mean fillet sample total PCBs concentration of 161.7 ppb_{ww} (rounded to 162 ppb_{ww} in Table 6-1), as shown in Table 1 of WDOH (2011), by assuming consumption of 70 percent for rainbow trout, 15 percent for mountain whitefish, and 15 percent for brown trout and "using the maximum value of the mean concentration for each species," as described above. WDOH's approach of using only the maximum values (e.g., using only the calculated average value from River Mile 77 to represent all mountain whitefish) to derive the weighted mean, rather than using the results across all sample stations, biases the derived weighted mean high and is not scientifically defensible. This practice also reduces the number of sample results available for this calculation from 25 to 7 (Table 6-1). When the more realistic "river-wide" approach is used, the calculated weighted mean is 102 ppb_{ww}, which yields a commensurate decrease in the calculated risks by a factor of 0.63 (102/161.7). This weighted mean total PCBs concentration is below the site-specific target of 135 ppb_{ww} (Section 5.3), which is based on a 95th percentile fish ingestion rate from Sunding (2019).

6.2 RELIANCE ON OLDER FISH ADVISORIES MISREPRESENTS CURRENT FISH CONSUMPTION ADVICE

As discussed above, the most recent fish tissue PCB data Dr. DeGrandchamp discusses in his Book 3 are from 2005. The most current fish consumption advisory he discusses is from 2007. Because he omits a more recent data set from 2012, which was used to develop the current fish advisories for the Spokane River (WDOH 2019), his interpretations are outdated. A robust fish tissue data set was collected in 2012 by Ecology and led to the recommendation that additional fish meals and species would be allowable for consumption, compared to the previous advisories. The current (2018/2019) fish advisory includes two additional river reaches (Little Falls Pool and Spokane Arm) where fish can now be consumed (1 to 4 meals per month, depending upon the species), increases the number of fish meals recommended for some species, and adds species for most of the remaining reaches (Table 5-1). For example, there was a "do not eat" advisory for largescale sucker in the Nine Mile Dam to Upriver Dam reach in the 2007 advisory, whereas two meals per month of largescale sucker can be consumed based on the 2018/2019 advisory.

Dr. DeGrandchamp's analysis states in several different ways that the fish advisories are attributable to PCB concentrations only, disregarding the other chemicals (PBDEs, lead, and mercury) that also factored into the fish advisory development. The 2018/2019 advisory clearly shows that only one advisory is based solely on PCBs (common carp in Long Lake). The remaining advisories are based on a combination of PCBs and the other contaminants, as shown

in Exhibit 5-2. The WDOH (2011) report states: "DOH is taking a precautionary approach by assuming joint additivity" (WDOH 2011, p. 6).

Dr. DeGrandchamp also neglects to explain that the Upriver Dam to Idaho border reach of the Spokane River is under a "catch and release only" advisory rather than an advisory due solely to the presence of PCBs and/or other chemicals. Exhibit 5-2 and the Silverbow Fly Shop (2019) explain the "do not eat" designation for that reach is based on protecting spawning populations of redband trout. Fish are safe to eat in this reach; however, anglers are not allowed to collect, keep fish caught from that river reach during spawning season. Consumptive fishing will be allowed to resume at the end of spawning season (Silverbow Fly Shop 2019).

6.3 UNDERLYING ASSUMPTIONS USED TO DEVELOP FISH ADVISORIES ARE NOT CONSISTENT WITH REAL-WORLD FISH CONSUMPTION RATES

Dr. DeGrandchamp provides a discussion of risks associated with the ingestion of fish at a rate of 42 g/day (on average) and 90 g/day for higher-end consumers. As I discussed in Section 5.2, the 42 g/day fish ingestion rate presented by WDOH (2007), which was cited as based on studies conducted in the late 1990s that were not specifically designed to estimate fish consumption rates, is likely in error. A similar consumption rate was reported in ATSDR (2005). Even so, WDOH uses the 42 g/day value only in its screening assessment. Fish advisories are set assuming an 8-oz meal size, which equates to 32 g/day for one fish meal per week. The error associated with the 42 g/day consumption rate also puts into question the derivation and use of the higher end consumption rate of 90 g/day.

As I discussed in Sections 4.3.2 and 5.3, Sunding (2019) estimated fish ingestion rates based on a recreational (including angling) survey of the Spokane River (Robinson Research 2015) and a larger recreational consumption and resource use survey for visitors to the Upper Columbia River, from the Grand Coulee Dam to the U.S.-Canada border and including a portion of the Spokane River (IEc 2013). Dr. Sunding's mean, 90th, and 95th percentile fish ingestion rates for anglers that consume fish from the Spokane River were calculated to be 4.4, 10, and 17 g/day, respectively (values are rounded to two significant digits). Even at the high end, this equates to one 8-oz meal every 2 weeks, or roughly two fish meals per month. The only fish species, based on the 2018/2019 fish advisory, that cannot be consumed at that rate are largescale sucker in the Spokane Arm and Upper Lake Spokane, brown trout in Upper Lake Spokane, and mountain whitefish from Nine Mile Dam to Upriver Dam (Table 5-1).

Furthermore, these advisories are based on one or more chemicals in addition to PCBs (PBDEs, lead, and/or mercury). As I illustrated in Section 5.3, fish tissue total PCBs concentrations are below a site-specific risk-based threshold that utilizes realistic and site-specific fish ingestion

rates, with the exception of mountain whitefish from Upriver Dam to Nine Mile Dam, which is not a highly preferred/consumed fish species.

6.4 RESULTS FROM THE WDOH/ATSDR HEALTH CONSULTATIONS WERE NOT PROPERLY INTERPRETED AND SUMMARIZED

Three collaborative WDOH and ATSDR health consultations have been prepared for the Spokane River or for portions of the river:

- ATSDR (2005): *Health Consultation, Evaluation of Polychlorinated Biphenyls (PCBs) in Fish from Long Lake (a.k.a. Long Spokane), Spokane, Washington*
- WDOH (2007): *Health Consultation, Evaluation of PCBs, PBDEs and Selected Metals in the Spokane River, Including Long Lake, Spokane, Washington*
- WDOH (2011): *Health Consultation, Potential Cumulative Health Effects Associated with Eating Spokane River Fish, Spokane, Spokane County, Washington.*

Dr. DeGrandchamp greatly skews his summary of ATSDR (2005) to emphasize the calculated noncancer and cancer risks and toxicity equivalence factor analysis of certain PCB congeners and, as a result, minimizes several important conclusions that communicate that PCBs do not pose a health risk to consumers of fish from Long Lake. His report lists three overall conclusions of ATSDR (2005) at the very end of his analysis, but he does not provide context or the further explanation that was presented for these conclusions in the source document. The conclusions appear as afterthoughts compared to the several pages discussing the risk calculations and toxicity equivalence factor analysis, which were only two parts of the many factors ATSDR considered in forming its recommendations (including actual health hazard potential, the health benefits of consuming fish, the reduction in PCBs from cooking and cleaning fish, and the potentially inflated safety factors used in the risk analysis). There are a total of 10 conclusions in ATSDR (2005); it is important to provide all of the conclusions together to get a complete understanding of the results of the study and the health recommendations provided. ATSDR clearly states that despite the risk analysis performed and potential toxicity of certain PCB congeners, the risk to consumers of Long Lake fish is minimal or nonexistent. This is evident in the following ATSDR (2005) report conclusions, which were not included in Dr. DeGrandchamp's report:

1. "Average consumers of sport fish from Long Lake are not expected to experience adverse health effects from exposure to contaminants in those fish. No apparent public health hazard exists for average consumers of Long Lake sport fish." (ATSDR 2005, p. 19)
2. "Polychlorinated biphenyls (PCBs) in popular sport-caught fish from Long Lake are generally lower than in the upper Spokane River. Consumption of sport fish from Long

Lake is preferred over the consumption of fish from other upstream portions of the Spokane River." (ATSDR 2005, p. 19)

3. "Although high-end consumers of fish from Long Lake might be exposed at doses above health comparison values, these doses are not expected to cause adverse health effects, especially when considering the safety factor of 300 that was applied to derive the MRL[15] … the health benefits of fish consumption, and the reduction of PCB levels through cooking and preparation." (ATSDR 2005, p. 19)

ATSDR (2005) further states that "[a]lthough this health consultation makes no meal limit recommendations for Long Lake fish, DOH recommends providing health education to Long Lake fish consumers including instructions on how to clean and cook fish in a manner that reduces a person's exposure to PCBs in their diet" (ATSDR 2005, p. 20).

Dr. DeGrandchamp's summary of WDOH (2007) misrepresents the conclusions regarding lead as a chemical of concern. Dr. DeGrandchamp states, "a determination was made to eliminate [lead] as a chemical of concern"; however, that is not entirely true. WDOH must consider lead a chemical of concern because it is still listed as one of the contaminants (along with PCBs and PBDEs) causing six separate advisories 12 years later, for three species of fish in Upper Long Lake and three species of fish in the reach from Nine Mile Dam to Upriver Dam (WDOH 2019).

Dr. DeGrandchamp also erroneously summarizes the results for lead in fish tissue that were reported in WDOH (2007). He states: "With one exception in which [lead] was detected only 0.02 ppm higher than the detection limit of 0.1 ppm, [lead] was not detected in any fish fillet sample" (p. 40). The *mean* was only 0.02 ppm higher than the detection limit at only one site (rainbow trout collected from Plante Ferry); there are maximum values above the detection limit for four additional sites/species. The table has these concentrations in bold due to the exceedance of not only the detection limit but also of the comparison value (see DeGrandchamp 2019, Exhibit 17, p. 41).

Dr. DeGrandchamp states that the assessment presented in WDOH (2011) shows that PCBs pose a cumulative lifetime cancer risk of 1.1×10^{-4} (one in ten thousand). He further states that the risk level "far exceeds the *de minimis* acceptable risk level by 100-fold and to reach acceptable risk levels the fish tissue levels must be reduced by 100-fold." Cancer (and noncancer) risks are always summarized to one significant digit per EPA's risk assessment guidance (USEPA 1989). The quoted risk level is within EPA's acceptable cancer risk range of 1×10^{-6} (one in a million) to 1×10^{-4} (one in ten thousand). Therefore, a reduction in fish tissue levels to achieve a risk level of $1\text{x}10^{-6}$ (one in a million) is not required. Further, his statement

[15] The MRL is the is the minimal risk level, and represents the dose below which health effects are not expected, and is similar to the chronic oral RfD.

that PCB risks far exceed "the *de minimis* acceptable risk level" is incongruous with his views expressed elsewhere where he states:

> "… the vast majority of toxicologists agree that thresholds do exist for many carcinogens. For example, it is estimated that on average more than a million DNA point mutations (involving chemical binding to DNA) occur in an average human daily. DNA repair processes and immunosurveillance are very effective in repairing cellular damage and most toxicologists consider these processes evidence of a threshold. These must be surmounted before neoplastic changes leading to tumor formation can occur. Nevertheless, the Agency has made a policy decision to view all potential carcinogens as lacking a threshold" (DeGrandchamp and Pyatt 2001 p. 4.).

Dr. DeGrandchamp also did not closely review WDOH's quoted risk results. These risk results were based on a consumption rate of 42 g/day, which, as stated earlier, is an error. The risk calculations should have been based on an 8-oz meal size, which equates to 32 g/day (at one fish meal per week). Use of this elevated fish consumption rate overestimates the potential risks by a factor of 1.3 (42/32).

6.5 MISREPRESENTS POTENTIAL EXPOSURES TO MINORITY POPULATIONS

DeGrandchamp (2019, p. 49) states that "certain ethnic communities around Spokane—including Russian and Laotian communities—regularly use the Spokane River as a food source and are therefore especially at risk." He bases this statement on SRHD (1998), but the SRHD document further states regarding these ethnic groups that "[t]he respondents of this study seemed to be low consumers of the fish from the Spokane River (< 1 fish meal/week) as defined by the study prepared by ATSDR." Such a consumption rate is not consistent with the statement that these groups "regularly use of the river as a food source," and the latter statement appears to be a misinterpretation of the information reported in SRHD (1998).

In my review of the publicly available consumption survey information, I was unable to find any additional reports beyond SRHD (1998) that assessed use of the river or assessed fish consumption rates by ethnic minorities. For example, a survey of river use by Robinson Research (2015) did not include any information on the respondents' ethnicity. Avista Corporation, which operates the hydroelectric dams on the river, has undertaken focused creel surveys of Long Lake as part of its operations permit. Neither its Long Lake creel survey performed in 2011 (Landau Associates 2012) nor the four proposed follow-up creel surveys[16] in Long Lake (Normandeau 2013) include documentation of the ethnicity of the anglers. This is not to say that information on the ethnicity of the angler is not important. Rather, the

[16] Normandeau (2013) reports that the follow-up creel surveys are scheduled to occur in 2016, 2018, 2020, and 2022, with a comprehensive report submitted to the Federal Energy Regulatory Commission in 2023.

information that is reported from SRHD (1998) shows that the consumption rate by ethnic minorities is already reflected in the distribution of fish consumption rates that I used in my assessment. Using the consumption rate of one fish meal per week from SRHD (1998) stated above and assuming a meal size of 8 oz (227 g) equates to an annualized daily consumption rate of 32 g/day, which is well within the range of fish consumption rates (0 to 157 g/day; Table 4-7) that I used in the PRA. Therefore, potential risks to all Spokane River consumers, including ethnic minorities, are addressed in the PRA.

6.6 MISREPRESENTS COMPARABILITY OF FISH ADVISORY AND RISK ASSESSMENT

In addition to not considering the most recent fish collections in 2012 and the resultant modifications to the fish advisories for the Spokane River, Dr. DeGrandchamp implies that consumption of fish in excess of fish advisories results in a risk to the consumer. There are differences in the methodologies used to develop fish advisories and to determine risks in the PRA. These differences are outlined in Table 6-2. Chief among these is that fish advisories establish recommendations on frequencies of fish meals (meals per week) by species that can be "safely" consumed by the public, based on generic assumptions applied state-wide. They do not calculate potential cancer or noncancer risks to the consumers of gamefish, and risks cannot be estimated from these values. A quantitative risk assessment (such as the PRA) calculates potential cancer and noncancer risks to consumers of Spokane River gamefish based on site-specific information, including local consumption rates. The advantage of the PRA is that it also calculates the potential risks across the range of fish concentrations, whereas the fish advisory is based on average fish concentrations.

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Figures

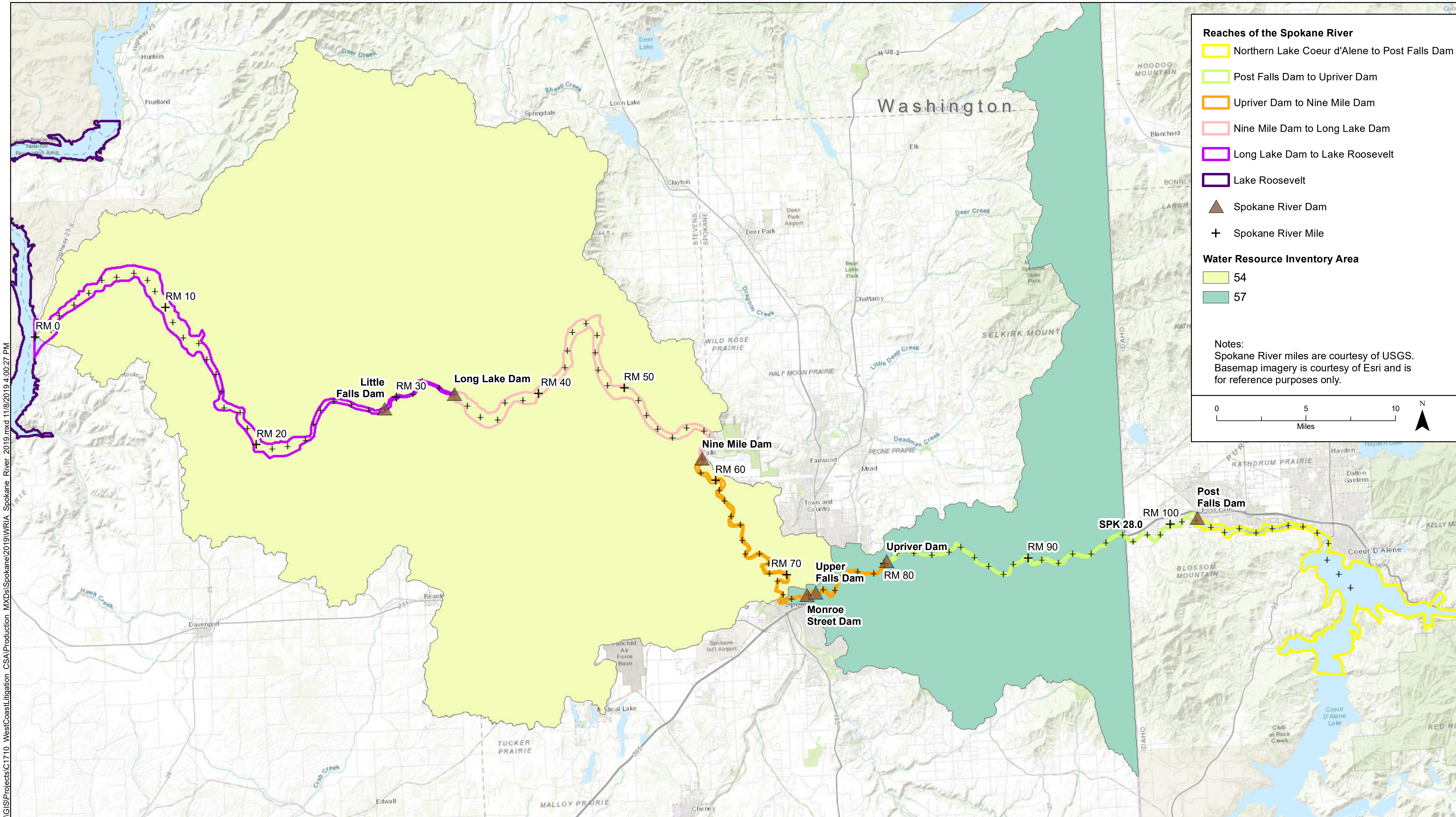

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Figure 4-1.
Water Resource Inventory Areas
Associated with the Spokane River

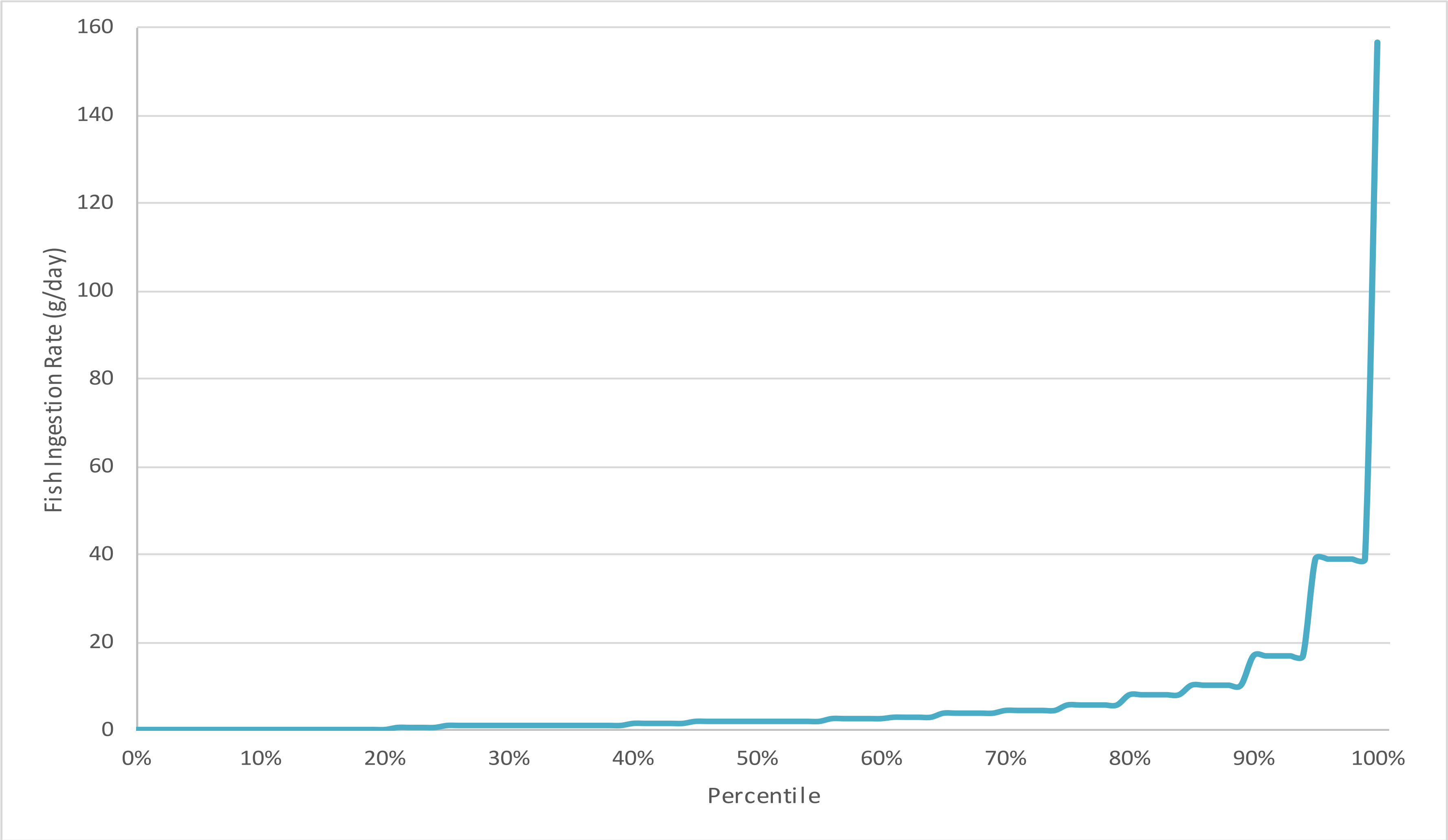

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Figure 4-2.
Adult Angler Fish Ingestion Rate Distribution (g/day)

Tables

Table 4-1. Common Exposure Parameters for Evaluation of Spokane River Surface Water and Sediment Exposure

Receptor	Sediment Ingestion Rate (mg/day)	Body Weight (kg)	Exposure Duration (years)[a]	Averaging Time (days) Cancer	Averaging Time (days) Noncancer[b]	Exposure Point Concentrations
Young Child (1–6 years)	200	19	6	25,550	2,190	See Tables 4-2a and 4-2b for surface water and sediment EPCs, respectively
Older Child (7–17 years)	100	50	11	25,550	4,015	
Adult (≥18 years)	100	80	9 / 15	25,550	3,285 / 5,475	

Notes:

[a] The total exposure duration among all age groups for all scenarios is 26 years. The duration for the adult for the shoreline and water recreation scenarios is 9 years (26–17 years, or the total duration for young and older child). Because only the older child and adult are evaluated for the recreational fishing scenario, the adult exposure duration is 15 years (26–11 years).

[b] Noncancer averaging time equals exposure duration x 365 days. For example, the exposure duration for the adult for the recreational fishing scenario is 15 years; thus, the averaging time is 5,475 days.

Table 4-2a. Summary of Total PCBs Concentrations (ppb) in Spokane River Surface Water

River Area	Collection Years	Frequency of Detection	Arithmetic Mean Total PCBs	Range of Detects	Range of Non-Detects	Congener Count Range	ProUCL Output			
							Distribution Type	Kaplan-Meier Mean	EPC (95UCL)	UCL Type
Spokane River (river-wide)	2003, 2012 to 2017	122/125	0.000153	0.000130 to 0.000434	0.0000409 to 0.000556	150 to 187	Approximate Normal	0.000143	0.000156	95% KM (t) UCL
Post Falls Dam to Upriver Dam	2003, 2012 to 2016	50/53	0.000129	0.0000246 to 0.000434	0.0000409 to 0.000556	150 to 187	Gamma	0.000124	0.000144	95% KM Approximate Gamma UCL
Upriver Dam to Nine Mile Dam	2003, 2012 to 2016	45/45	0.000189	0.0000169 to 0.000418	---	159 to 187	Normal	NC	0.000209	95% Student's-t UCL
Nine Mile Dam to Long Lake Dam	2014 and 2016	14/14	0.000183	0.0000871 to 0.000245	---	159 to 159	Normal	NC	0.000203	95% Student's-t UCL
Long Lake Dam to Lake Roosevelt	2012, 2013, 2016 and 2017	13/13	0.0000197	0.000000914 to 0.000048	---	159 to 187	Normal	NC	0.0000262	95% Student's-t UCL

Notes:

Surface water results are from seven studies and represent $TotPCB_{cong}$ only. Individual sample results are provided in Appendix Table B-2b.

Mean and UCL values shown are rounded to 3 significant digits.

ProUCL (v5.11) was used to derive the distribution types, Kaplan-Meier Means, 95UCL values, and UCL Types.

Kaplan-Meier mean is calculated only when the frequency of detection is less than 100%.

Arithmetic mean is calculated by setting non-detects to one-half the reported detection limits.

A dash ('---") indicates the calculation was not required.

EPC = exposure point concentration

KM = Kaplan-Meier statistical parameter

NC = No calculations. Due to small number of sample results and low detection frequency ProUCL did not perform any summary calculations.

PCB = polychlorinated biphenyl

UCL = upper confidence limit

Table 4-2b. Summary of Total PCBs Concentrations (ppb) in Spokane River Surface Sediments

River Area	Collection Years	Summary Statistics: Frequency of Detection	Half-DL Arithmetic Mean	Range of Positive Results	Range of Detection Limits for Non-Detect Results	ProUCL Output: Distribution Type	KM Mean[a]	Mean Type	95UCL[b]	Basis for 95UCL Recommended by ProUCL
Spokane River (river-wide)	2003, 2004, 2013	48/61	25.2	1.90 to 330	2.1 to 9.9	Approximate Lognormal	8.857	KM Geomean	32.5	95% H-UCL (KM -Log)
Post Falls Dam to Upriver Dam	2003, 2004	27/40	26.6	2.3 to 330	2.1 to 9.9	Lognormal	7.72	KM Geomean	36.0	95% H-UCL (KM -Log)
Upriver Dam to Nine Mile Dam	2003, 2004, 2013	13/13	21.0	2.44 to 97	---	Approximate Gamma	---	---	47.4	95% Adjusted Gamma UCL
Nine Mile Dam to Long Lake Dam	2003, 2004	6/6	32.0	20.8 to 49.7	---	Normal	---	----	42.0	95% Student's-t UCL
Long Lake Dam to Lake Roosevelt	2003	2/2	6.15	1.9 to 10.4	---	NC	---	NC	NC	Maximum detection used as UCL

Notes:

All concentration units are in ppb_{dw}.

Half-DL Arithmetic Mean, KM Mean values and 95^{th}% UCL values are rounded to three significant digits in this table.

Total PCBs were based on the sum of the detected Aroclor PCBs or sum of detected PCB congeners.

Frequency of detection: The ratio of the counts of detected results and the total number of results.

A dash ('---") indicates that the value was not calculated or not required.

DL = detection limit

NC = No calculations. Due to small number of sample results and low detection frequency ProUCL did not perform any summary calculations.

PCB = polychlorinated biphenyl

ppb_{dw} = parts per billion dry weight

UCL = upper confidence limit

[a] KM Mean is the Kaplan-Meier Mean concentration that was calculated by EPA's ProUCL software (v 5.1) when the detection frequency is less than 100%.

[b] The 95UCL is the 95^{th} percentile upper confidence limit for the arithmetic mean concentration that was calculated using EPA's ProUCL software (v 5.1).

Table 4-3. Scenario-Specific Exposure Parameters for Evaluation of Spokane River Surface Water and Sediment Exposure

	Shoreline Recreation						Water Recreation						Recreational Fishing			
	Sediment			Surface Water			Sediment			Surface Water			Sediment		Surface Water	
Exposure Parameter	Young Child	Older Child	Adult	Young Child	Older Child	Adult	Young Child	Older Child	Adult	Young Child	Older Child	Adult	Older Child	Adult	Older Child	Adult
Surface water Ingestion Rate (mL/hr)	NA	NA	NA	96	152	92	NA	NA	NA	19.9	19.9	19.9	NA	NA	NA	NA
Skin Surface Area (cm^2)	3,848	7,994	5,936	7,502	14,502	19,771	2,103	4,267	5,936	2,103	4,267	5,936	1,610	2,214	4,267	5,936
Adherence (mg/cm^2)	0.57	0.58	0.36	NA	NA	NA	0.61	0.62	0.36	NA	NA	NA	0.79	0.71	NA	NA
Exposure Frequency (days/yr)	40	40	40	40	40	40	21	21	21	21	21	21	10	10	10	10
Exposure Time (hr/day)	NA	NA	NA	0.3	0.3	0.3	NA	NA	NA	4	4	4	NA	NA	4	4

Notes:
NA = not applicable

Table 4-4. Age- and Activity-Specific Skin Surface Areas for Evaluation of Spokane River Surface Water and Sediment Exposure

Age (male and female combined)	Mean Surface Areas by Body Part (cm^2)								Combined Mean Surface Areas (cm^2)			
	Head	Trunk	Arms	Forearms	Hands	Legs	Lower Legs	Feet	Whole Body[a]	Hands, Arms, Legs and Feet[b]	Hands, Forearms, Lower Legs, Feet[c]	Hands and Feet[d]
1 year	870	1,880	690	311	300	1,220	488	330	5,290	2,540	1,429	630
2 years	510	2,500	880	396	280	1,540	616	380	6,090	3,080	1,672	660
3 years	610	3,130	1,060	477	370	1,950	780	490	7,610	3,870	2,117	860
4 years	610	3,130	1,060	477	370	1,950	780	490	7,610	3,870	2,117	860
5 years	610	3,130	1,060	477	370	1,950	780	490	7,610	3,870	2,117	860
6 years	660	4,280	1,510	680	510	3,110	1,244	730	10,800	5,860	3,164	1,240
1 to <7 years	**645**	**3,008**	**1,043**	**470**	**367**	**1,953**	**781**	**485**	**7,502**	**3,848**	**2,103**	**852**
7 years	660	4,280	1,510	680	510	3,110	1,244	730	10,800	5,860	3,164	1,240
8 years	660	4,280	1,510	680	510	3,110	1,244	730	10,800	5,860	3,164	1,240
9 years	660	4,280	1,510	680	510	3,110	1,244	730	10,800	5,860	3,164	1,240
10 years	660	4,280	1,510	680	510	3,110	1,244	730	10,800	5,860	3,164	1,240
11 years	730	6,300	2,270	1,022	720	4,830	1,932	1,050	15,900	8,870	4,724	1,770
12 years	730	6,300	2,270	1,022	720	4,830	1,932	1,050	15,900	8,870	4,724	1,770
13 years	730	6,300	2,270	1,022	720	4,830	1,932	1,050	15,900	8,870	4,724	1,770
14 years	730	6,300	2,270	1,022	720	4,830	1,932	1,050	15,900	8,870	4,724	1,770
15 years	730	6,300	2,270	1,022	720	4,830	1,932	1,050	15,900	8,870	4,724	1,770
16 years	750	7,590	2,690	1,211	830	5,430	2,172	1,120	18,410	10,070	5,333	1,950
17 years	750	7,590	2,690	1,211	830	5,430	2,172	1,120	18,410	10,070	5,333	1,950
7 to <18 years	**708**	**5,800**	**2,070**	**932**	**664**	**4,314**	**1,725**	**946**	**14,502**	**7,994**	**4,267**	**1,610**
18 years	750	7,590	2,690	1,211	830	5,430	2,172	1,120	18,410	NA	5,333	1,950
19 years	750	7,590	2,690	1,211	830	5,430	2,172	1,120	18,410	NA	5,333	1,950
20 years	750	7,590	2,690	1,211	830	5,430	2,172	1,120	18,410	NA	5,333	1,950
21 years	1,250	7,405	2,755	1,240	980	6,400	2,560	1,295	20,085	NA	6,075	2,275
22 years	1,250	7,405	2,755	1,240	980	6,400	2,560	1,295	20,085	NA	6,075	2,275
23 years	1,250	7,405	2,755	1,240	980	6,400	2,560	1,295	20,085	NA	6,075	2,275
24 years	1,250	7,405	2,755	1,240	980	6,400	2,560	1,295	20,085	NA	6,075	2,275
25 years	1,250	7,405	2,755	1,240	980	6,400	2,560	1,295	20,085	NA	6,075	2,275
26 years	1,250	7,405	2,755	1,240	980	6,400	2,560	1,295	20,085	NA	6,075	2,275
27 years	1,250	7,405	2,755	1,240	980	6,400	2,560	1,295	20,085	NA	6,075	2,275
28 years	1,250	7,405	2,755	1,240	980	6,400	2,560	1,295	20,085	NA	6,075	2,275
29 years	1,250	7,405	2,755	1,240	980	6,400	2,560	1,295	20,085	NA	6,075	2,275
30 years	1,250	7,405	2,755	1,240	980	6,400	2,560	1,295	20,085	NA	6,075	2,275
31 years	1,250	7,405	2,755	1,240	980	6,400	2,560	1,295	20,085	NA	6,075	2,275
32 years	1,250	7,405	2,755	1,240	980	6,400	2,560	1,295	20,085	NA	6,075	2,275
33 years +	1,250	7,405	2,755	1,240	980	6,400	2,560	1,295	20,085	NA	6,075	2,275
18 to < 34 years	**1,156**	**7,440**	**2,743**	**1,234**	**952**	**6,218**	**2,487**	**1,262**	**19,771**	**NA**	**5,936**	**2,214**

Table 4-4. Age- and Activity-Specific Skin Surface Areas for Evaluation of Spokane River Surface Water and Sediment Exposure

Source: USEPA (2011). Values provided in source are in units of m^2. Values have been converted to cm^2 as follows: 1 m^2 = 10,000 cm^2.

Notes:

Values not reported in USEPA (2011). Forearms calculated as 45% of arms, and lower legs calculated as 40% of legs per USEPA (2004a).

All values are males and females combined

NA = not applicable

[a] Used to evaluate potential dermal contact while swimming for all age groups.

[b] Used to evaluate direct contact of young children and older children with sediment as part of the shoreline and water recreation scenarios.

[c] Used to evaluate direct contact of young children, older children, and adults with sediment and surface water, as part of the water recreation scenario. Also used to evaluate direct contact of adults with sediment as part of the shoreline recreation scenario, and to evaluate direct contact of older children and adults with surface water during fishing from shore.

[d] Used to evaluate potential dermal contact with sediment while fishing from shore.

Table 4-5. Sediment Adherence Factors for Children Engaged in Shoreline and Water Recreation and Recreational Fishing, for Evaluation of Spokane River Sediment Exposure

											Shoreline Recreation		Water Recreation		Recreational Fishing	
Male and Female Combined	Surface Area Arms (cm^2)	Surface Area Forearms (cm^2)[a]	Adherence Factor for Arms (mg/cm^2)	Surface Area Hands (cm^2)[a]	Adherence Factor for Hands (mg/cm^2)	Surface Area Legs (cm^2)[a]	Surface Area Lower Legs (cm^2)[a]	Adherence Factor for Legs (mg/cm^2)	Surface Area Feet (cm^2)[a]	Adherence Factor for Feet (mg/cm^2)[b]	Sum of Surface Area of Arms, Hands, Legs and Feet (cm^2)	Surface Area Weighted Adherence Factor (mg/cm^2)	Sum of Surface Area of Forearms, Hands, Lower Legs and Feet (cm^2)	Surface Area Weighted Adherence Factor (mg/cm^2)	Sum of Surface Area of Hands and Feet (cm^2)	Weighted Adherence Factor (mg/cm^2)
1 year	690	311	0.17	300	0.49	1,220	488	0.7	330	1	2,540	0.57	1,429	0.61	NA	NA
2 years	880	396	0.17	280	0.49	1,540	616	0.7	380	1	3,080	0.57	1,672	0.61	NA	NA
3 years	1,060	477	0.17	370	0.49	1,950	780	0.7	490	1	3,870	0.57	2,117	0.61	NA	NA
4 years	1,060	477	0.17	370	0.49	1,950	780	0.7	490	1	3,870	0.57	2,117	0.61	NA	NA
5 years	1,060	477	0.17	370	0.49	1,950	780	0.7	490	1	3,870	0.57	2,117	0.61	NA	NA
6 years	1,510	680	0.17	510	0.49	3,110	1,244	0.7	730	1	5,860	0.58	3,164	0.62	NA	NA
1 to < 7 years	**1,043**	**470**	**0.17**	**367**	**0.49**	**1,953**	**781**	**0.7**	**485**	**1**	**3,848**	**0.57**	**2,103**	**0.61**		
7 years	1,510	680	0.17	510	0.49	3,110	1,244	0.7	730	1	5,860	0.58	3,164	0.62	1,240	0.79
8 years	1,510	680	0.17	510	0.49	3,110	1,244	0.7	730	1	5,860	0.58	3,164	0.62	1,240	0.79
9 years	1,510	680	0.17	510	0.49	3,110	1,244	0.7	730	1	5,860	0.58	3,164	0.62	1,240	0.79
10 years	1,510	680	0.17	510	0.49	3,110	1,244	0.7	730	1	5,860	0.58	3,164	0.62	1,240	0.79
11 years	2,270	1,022	0.17	720	0.49	4,830	1,932	0.7	1,050	1	8,870	0.58	4,724	0.62	1,770	0.79
12 years	2,270	1,022	0.17	720	0.49	4,830	1,932	0.7	1,050	1	8,870	0.58	4,724	0.62	1,770	0.79
13 years	2,270	1,022	0.17	720	0.49	4,830	1,932	0.7	1,050	1	8,870	0.58	4,724	0.62	1,770	0.79
14 years	2,270	1,022	0.17	720	0.49	4,830	1,932	0.7	1,050	1	8,870	0.58	4,724	0.62	1,770	0.79
15 years	2,270	1,022	0.17	720	0.49	4,830	1,932	0.7	1,050	1	8,870	0.58	4,724	0.62	1,770	0.79
16 years	2,690	1,211	0.17	830	0.49	5,430	2,172	0.7	1,120	1	10,070	0.57	5,333	0.61	1,950	0.78
17 years	2,690	1,211	0.17	830	0.49	5,430	2,172	0.7	1,120	1	10,070	0.57	5,333	0.61	1,950	0.78
7 to <18 years	**2,070**	**932**	**0.17**	**664**	**0.49**	**4,314**	**1,725**	**0.7**	**946**	**1**	**7,994**	**0.58**	**4,267**	**0.62**	**1,610**	**0.79**

Source: Adherence factors reported by USEPA (2011) for children playing in sediment, shoreline play (USEPA 2011: Tables 7-4 and 7-20).

Notes:

All values are for males and females combined.

NA = not applicable

[a] Surface areas are calculated in Table 4-4. Areas of forearms and lower legs are estimated as 45% of arms and 40% of legs, respectively, per USEPA (2004a).

[b] Maximum adherence factor of 1 mg/cm^2 used for feet (see text).

Table 4-6. Sediment Adherence Factors for Adults Engaged in Shoreline and Water Recreation and Recreational Fishing, for Evaluation of Spokane River Sediment Exposure

											Shoreline and Water Recreation		Recreational Fishing	
Male and Female Combined	Arms (cm^2)[a]	Forearms (cm^2)[a]	Adherence Factor for Arms (mg/cm^2)	Hands (cm^2)[a]	Adherence Factor for Hands (mg/cm^2)	Legs (cm^2)[a]	Lower Legs (cm^2)[a]	Adherence Factor for Legs (mg/cm^2)	Feet (cm^2)[a]	Adherence Factor for Feet (mg/cm^2)	Total Surface Area of Forearms, Hands, Lower Legs and Feet (cm^2)	Surface Area Weighted Adherence Factor (mg/cm^2)	Total Surface Area of Hands and Feet (cm^2)	Surface Area Weighted Adherence Factor (mg/cm^2)
18 years	2,690	1,211	0.12	830	0.88	5,430	2,172	0.16	1,120	0.58	5,333	0.35	1,950	0.71
19 years	2,690	1,211	0.12	830	0.88	5,430	2,172	0.16	1,120	0.58	5,333	0.35	1,950	0.71
20 years	2,690	1,211	0.12	830	0.88	5,430	2,172	0.16	1,120	0.58	5,333	0.35	1,950	0.71
21 years	2,755	1,240	0.12	980	0.88	6,400	2,560	0.16	1,295	0.58	6,075	0.36	2,275	0.71
22 years	2,755	1,240	0.12	980	0.88	6,400	2,560	0.16	1,295	0.58	6,075	0.36	2,275	0.71
23 years	2,755	1,240	0.12	980	0.88	6,400	2,560	0.16	1,295	0.58	6,075	0.36	2,275	0.71
24 years	2,755	1,240	0.12	980	0.88	6,400	2,560	0.16	1,295	0.58	6,075	0.36	2,275	0.71
25 years	2,755	1,240	0.12	980	0.88	6,400	2,560	0.16	1,295	0.58	6,075	0.36	2,275	0.71
26 years	2,755	1,240	0.12	980	0.88	6,400	2,560	0.16	1,295	0.58	6,075	0.36	2,275	0.71
27 years	2,755	1,240	0.12	980	0.88	6,400	2,560	0.16	1,295	0.58	6,075	0.36	2,275	0.71
28 years	2,755	1,240	0.12	980	0.88	6,400	2,560	0.16	1,295	0.58	6,075	0.36	2,275	0.71
29 years	2,755	1,240	0.12	980	0.88	6,400	2,560	0.16	1,295	0.58	6,075	0.36	2,275	0.71
30 years	2,755	1,240	0.12	980	0.88	6,400	2,560	0.16	1,295	0.58	6,075	0.36	2,275	0.71
31 years	2,755	1,240	0.12	980	0.88	6,400	2,560	0.16	1,295	0.58	6,075	0.36	2,275	0.71
32 years	2,755	1,240	0.12	980	0.88	6,400	2,560	0.16	1,295	0.58	6,075	0.36	2,275	0.71
33 years +	2,755	1,240	0.12	980	0.88	6,400	2,560	0.16	1,295	0.58	6,075	0.36	2,275	0.71
Adult											**5,936**	**0.36**	**2,214**	**0.71**

Source: Adherence factors reported by USEPA 2011 for sediment exposure, clamming activity (USEPA 2011: Table 7-20).

Notes:

[a] Surface areas are calculated in Table 4-4. Areas of forearms and lower legs are estimated as 45% of arms and 40% of legs, respectively, per USEPA (2004a).

Table 4-7. River-wide Fish Ingestion Rate Distributions Based on IEc (2013) Survey Data

Statistic	Adult Angler[a]	Adult Angler who Shares Fish with Children[b]	Young Child Angler[c]
Sample Size	30,600	--	13,200
Mean	4.38	3.22	0.97
1st Percentile	0.00	0.00	0.00
5th Percentile	0.00	0.00	0.00
10th Percentile	0.00	0.00	0.00
15th Percentile	0.00	0.00	0.00
20th Percentile	0.00	0.00	0.00
25th Percentile	0.47	0.00	0.00
30th Percentile	0.93	0.00	0.00
35th Percentile	0.93	0.00	0.00
40th Percentile	0.93	0.00	0.00
45th Percentile	1.40	0.00	0.00
50th Percentile	1.86	0.00	0.00
55th Percentile	1.86	0.00	0.00
60th Percentile	2.49	0.00	0.00
65th Percentile	2.80	0.93	0.28
70th Percentile	3.73	1.55	0.47
75th Percentile	4.35	3.11	0.93
80th Percentile	5.59	4.19	1.26
85th Percentile	7.92	6.99	2.10
90th Percentile	10.10	9.32	2.80
95th Percentile	16.78	14.91	4.47
99th Percentile	38.84	37.28	11.18
Maximum	156.58	156.58	46.97

Notes:

-- = not provided in source table

PRA = probabilistic risk assessment

[a] Adult angler fish ingestion rate distribution used in this PRA. As calculated by Sunding (2019) based on the raw survey data from the IEc (2013) study. Percentiles shown are for “residents who consume fish from the Spokane River” (Appendix C, Appendix Table 1).

[b] Distribution used to calculate the young child angler fish ingestion rate distribution. As calculated by Sunding (2019) based on the raw survey data from the IEc (2013) study. Percentiles shown are for “anglers who share with children” (Appendix C, Appendix Table 5).

[c] Young child angler fish ingestion rate distribution used in this PRA. As calculated by Sunding (2019) based on the ingestion rates for adult anglers who share fish with children and a child-to-adult fish consumption rate ratio of 0.3 (Appendix C, Appendix Table 5).

Table 4-8. Species Preference Percentages (as fractions) based on IEc (2013) Survey Data

Species Group	Species Associated with Species Group	Data Reported in Sunding (2019)[a]	River-Wide + Lake Roosevelt Species Preferences[b]	River Reach-Specific Species/Group Preference Values[c]			
				Post Falls Dam to Upriver Dam	Upriver Dam to Nine Mile Dam	Nine Mile Dam to Long Lake Dam	Long Lake Dam to Lake Roosevelt
Bass Group	Smallmouth bass Largemouth bass White crappie	0.071	0.071	--	--	0.14	--
Perch Group	Yellow perch	0.0037	0.0037	--	--	0.0075	--
Salmon Group	Mountain whitefish	0.063	0.063	--	0.15	0.13	--
Trout Group	Brown trout Rainbow trout	0.353	0.35	1.0	0.85	0.72	1.0
Walleye Group	Walleye	0.504	0.51	--	--	--	--
Other	Various[d]	0.0060	--	--	--	--	--
Total		1.0	1.0	1.0	1.0	1.0	1.0

Notes:

-- = not applicable; no species group-specific PCB data are available for this area of the river

PCB = polychlorinated biphenyl

PRA = probabalistic risk assessment

[a] As calculated by Sunding (2019) based on the raw survey data from the IEc (2013) study (Appendix C, Appendix Table 3).

[b] Re-scaled to adjust for a lack of PCB data in the PRA fish tissue data set that belong in the "other" species group.

[c] Each set of river reach-specific species preferences is re-scaled based on the PCB data available for the particular river reach.

[d] Species not typically consumed were categorized as "other" and excluded from the PRA.

Table 4-9. Summary of Total PCBs Concentrations in PRA Gamefish Collected from the Spokane River and Lake Roosevelt

River Area	PRA Gamefish Groups	Collection Years	Frequency of Detection[a]	Half-DL Arithmetic Mean	KM Mean[b]	Range of Positive Results	Range of Detection Limits for Non-detect Results
Spokane River (River-wide) plus Lake Roosevelt	All Gamefish	2001, 2003, 2005, 2012	111/122	64.3	64.4	1.7 to 280	9.6 to 11
	Bass Group	2001 and 2005	15/16	52.8	53.1	31 to 101	11 to 11
	Perch Group	2001	0/6	ND	--	--	10 to 11
	Salmon Group	2001, 2005, and 2012	36/37	122	122	16.3 to 280	9.6 to 9.6
	Trout Group	2003, 2005, and 2012	54/57	42.9	43.0	5.7 to 220	9.7 to 9.7
	Walleye Group	2005	6/6	3.9	--	1.7 to 6	--
Post Falls Dam to Upriver Dam	All Gamefish	2003, 2005, and 2012	8/8	42.4	---	25.4 to 68	----
	Trout Group	2003, 2005 and 2012	8/8	42.4	---	25.4 to 68	----
Upriver Dam to Nine Mile Dam	All Gamefish	2003, 2005 and 2012	54/54	87.1	---	9.7 to 280	---
	Salmon Group	2005 and 2012	18/18	163	---	53.9 to 280	---
	Trout Group	2003, 2005, and 2012	36/36	49.3	---	9.7 to 220	---
Nine Mile Dam to Long Lake Dam	All Gamefish	2001, 2005, and 2012	35/43	60.9	61.8	16.3 to 213	9.6 to 11
	Bass Group	2001, 2005	15/16	52.8	53.1	31 to 101	11 to 11
	Perch Group	2001	0/6	ND	ND	---	10 to 11
	Salmon Group	2001, 2005, and 2012	18/19	83.0	83.3	16.3 to 213	9.6 to 9.6
	Trout Group	2005 and 2012	2/2	83.5	---	37 to 130	---
Long Lake Dam to Lake Roosevelt	All Gamefish	2012	3/6	21.3	23.8	15.4 to 59	9.7 to 9.7
	Trout Group	2012	3/6	21.3	23.8	15.4 to 59	9.7 to 9.7
Lake Roosevelt	All Gamefish	2005	11/11	5.61	---	1.7 to 10.8	---
	Trout Group	2005	5/5	7.66	---	5.7 to 10.8	---
	Walleye Group	2005	6/6	3.90	---	1.7 to 6	---

Notes:

All concentration units are in ppb_{ww}.

Total PCBs are based on the sum of the detected Aroclor PCBs or sum of detected PCB congeners.

Only results for fillet/skin-on tissue type are shown in this table.

Sample-field duplicate pairs were averaged for the fish tissue total PCB calculations.

See Appendix Table B-4d for additional details.

-- = value not calculated/required

DL = detection limit

ND = not detected

PCB = polychlorinated biphenyl

ppb_{ww} = parts per billion wet weight

PRA = probabalistic risk assessment

[a] Ratio of the counts of detected results to the total number of results.

[b] KM mean is the Kaplan-Meier mean concentration that was calculated by EPA's ProUCL software (v 5.1) when the detection frequency is less than 100 percent.

Table 4-10. Cooking Loss Percentages for PCBs, with and without Outlier Values[a]

Statistic	All Data	Without Outlier Values[b]
Mean	32	33
Median	30	30
Count	79	77
Minimum	-17	0
10th Percentile	13	15
25th Percentile	21	23
50th Percentile	30	30
75th Percentile	42	43
90th Percentile	53	54
Maximum	74	74

Notes:

[a] Source: AECOM (2012)

[b] Two negative values were identified as outliers and excluded from the values shown.

Table 4-11. Hypothetical Cancer Risks Associated with Shoreline Recreation

River Area	Exposure Medium	Exposure Pathway	Adult LADD (mg/kg-day)	Adult Cancer Risk	Older Child LADD (mg/kg-day)	Older Child Cancer Risk	Young Child LADD (mg/kg-day)	Young Child Cancer Risk	Total Risk
Spokane River (River-wide)	Sediment	Ingestion	6E-10	1E-09	1E-09	2E-09	3E-09	6E-09	1E-08
		Dermal	2E-09	3E-09	7E-09	1E-08	5E-09	1E-08	3E-08
	Surface Water	Ingestion	8E-13	3E-13	2E-12	1E-12	2E-12	9E-13	2E-12
		Dermal	6E-10	1E-09	9E-10	2E-09	6E-10	1E-09	4E-09
								Total Lifetime Risk	**4E-08**
Post Falls Dam to Upriver Dam	Sediment	Ingestion	6E-10	1E-09	1E-09	2E-09	4E-09	7E-09	1E-08
		Dermal	2E-09	4E-09	8E-09	2E-08	6E-09	1E-08	3E-08
	Surface Water	Ingestion	2E-12	9E-13	7E-12	3E-12	6E-12	3E-12	6E-12
		Dermal	2E-09	3E-09	2E-09	5E-09	2E-09	4E-09	1E-08
								Total Lifetime Risk	**5E-08**
Upriver Dam to Nine Mile Dam	Sediment	Ingestion	8E-10	2E-09	2E-09	3E-09	5E-09	9E-09	1E-08
		Dermal	2E-09	5E-09	1E-08	2E-08	7E-09	1E-08	4E-08
	Surface Water	Ingestion	1E-12	4E-13	3E-12	1E-12	3E-12	1E-12	3E-12
		Dermal	8E-10	2E-09	1E-09	2E-09	8E-10	2E-09	6E-09
								Total Lifetime Risk	**6E-08**
Nine Mile Dam to Long Lake Dam	Sediment	Ingestion	7E-10	1E-09	1E-09	3E-09	4E-09	8E-09	1E-08
		Dermal	2E-09	4E-09	9E-09	2E-08	6E-09	1E-08	4E-08
	Surface Water	Ingestion	1E-12	4E-13	3E-12	1E-12	3E-12	1E-12	3E-12
		Dermal	8E-10	2E-09	1E-09	2E-09	8E-10	2E-09	5E-09
								Total Lifetime Risk	**5E-08**
Long Lake Dam to Lake Roosevelt	Sediment	Ingestion	2E-10	4E-10	4E-10	7E-10	1E-09	2E-09	3E-09
		Dermal	5E-10	1E-09	2E-09	5E-09	2E-09	3E-09	9E-09
	Surface Water	Ingestion	1E-13	5E-14	4E-13	2E-13	4E-13	1E-13	4E-13
		Dermal	1E-10	2E-10	1E-10	3E-10	1E-10	2E-10	7E-10
								Total Lifetime Risk	**1E-08**

Notes:
LADD = lifetime average daily dose

Table 4-12. Hypothetical Cancer Risks Associated with Water Recreation

River Area	Exposure Medium	Exposure Pathway	Adult LADD (mg/kg-day)	Adult Cancer Risk	Older Child LADD (mg/kg-day)	Older Child Cancer Risk	Young Child LADD (mg/kg-day)	Young Child Cancer Risk	Total Risk
Spokane River (River-wide)	Sediment	Ingestion	3E-10	6E-10	6E-10	1E-09	2E-09	3E-09	5E-09
		Dermal	9E-10	2E-09	2E-09	4E-09	2E-09	3E-09	9E-09
	Surface Water	Ingestion	1E-12	5E-13	2E-12	9E-13	3E-12	1E-12	3E-12
		Dermal	3E-10	7E-10	5E-10	1E-09	3E-10	7E-10	2E-09
								Total Lifetime Risk	**2E-08**
Post Falls Dam to Upriver Dam	Sediment	Ingestion	3E-10	7E-10	6E-10	1E-09	2E-09	4E-09	6E-09
		Dermal	1E-09	2E-09	2E-09	5E-09	2E-09	3E-09	1E-08
	Surface Water	Ingestion	3E-12	1E-12	6E-12	3E-12	9E-12	4E-12	7E-12
		Dermal	1E-09	2E-09	1E-09	3E-09	1E-09	2E-09	7E-09
								Total Lifetime Risk	**2E-08**
Upriver Dam to Nine Mile Dam	Sediment	Ingestion	4E-10	9E-10	9E-10	2E-09	2E-09	5E-09	8E-09
		Dermal	1E-09	3E-09	3E-09	6E-09	2E-09	4E-09	1E-08
	Surface Water	Ingestion	2E-12	6E-13	3E-12	1E-12	4E-12	2E-12	4E-12
		Dermal	5E-10	9E-10	6E-10	1E-09	5E-10	9E-10	3E-09
								Total Lifetime Risk	**2E-08**
Nine Mile Dam to Long Lake Dam	Sediment	Ingestion	4E-10	8E-10	8E-10	2E-09	2E-09	4E-09	7E-09
		Dermal	1E-09	2E-09	3E-09	6E-09	2E-09	4E-09	1E-08
	Surface Water	Ingestion	1E-12	6E-13	3E-12	1E-12	4E-12	2E-12	3E-12
		Dermal	4E-10	9E-10	6E-10	1E-09	4E-10	9E-10	3E-09
								Total Lifetime Risk	**2E-08**
Long Lake Dam to Lake Roosevelt	Sediment	Ingestion	1E-10	2E-10	2E-10	4E-10	5E-10	1E-09	2E-09
		Dermal	3E-10	6E-10	7E-10	1E-09	5E-10	1E-09	3E-09
	Surface Water	Ingestion	2E-13	8E-14	4E-13	1E-13	5E-13	2E-13	4E-13
		Dermal	6E-11	1E-10	8E-11	2E-10	6E-11	1E-10	4E-10
								Total Lifetime Risk	**5E-09**

Notes:
LADD = lifetime average daily dose

Table 4-13. Hypothetical Cancer Risks Associated with Recreational Fishing[a]

River Area	Exposure Medium	Exposure Pathway	Adult LADD (mg/kg-day)	Adult Cancer Risk	Older Child LADD (mg/kg-day)	Older Child Cancer Risk	Total Risk
Spokane River (River-wide)	Sediment	Ingestion	2E-10	5E-10	3E-10	6E-10	1E-09
		Dermal	5E-10	1E-09	5E-10	1E-09	2E-09
	Surface Water	Dermal	3E-10	5E-10	2E-10	5E-10	1E-09
						Total Lifetime Risk	**4E-09**
Post Falls Dam to Upriver Dam	Sediment	Ingestion	3E-10	5E-10	3E-10	6E-10	1E-09
		Dermal	6E-10	1E-09	5E-10	1E-09	2E-09
	Surface Water	Dermal	8E-10	2E-09	6E-10	1E-09	3E-09
						Total Lifetime Risk	**6E-09**
Upriver Dam to Nine Mile Dam	Sediment	Ingestion	3E-10	7E-10	4E-10	8E-10	2E-09
		Dermal	8E-10	2E-09	7E-10	1E-09	3E-09
	Surface Water	Dermal	4E-10	7E-10	3E-10	6E-10	1E-09
						Total Lifetime Risk	**6E-09**
Nine Mile Dam to Long Lake Dam	Sediment	Ingestion	3E-10	6E-10	4E-10	7E-10	1E-09
		Dermal	7E-10	1E-09	6E-10	1E-09	3E-09
	Surface Water	Dermal	4E-10	7E-10	3E-10	6E-10	1E-09
						Total Lifetime Risk	**5E-09**
Long Lake Dam to Lake Roosevelt	Sediment	Ingestion	8E-11	2E-10	9E-11	2E-10	3E-10
		Dermal	2E-10	3E-10	2E-10	3E-10	7E-10
	Surface Water	Dermal	5E-11	9E-11	4E-11	8E-11	2E-10
						Total Lifetime Risk	**1E-09**

Notes:

LADD = lifetime average daily dose

[a] Only the older child and adult were evaluated for recreational fishing; the young child is less likely to fish (see text for further explanation).

Table 4-14. Hypothetical Noncancer Risks Associated with Shoreline Recreation

River Area	Exposure Medium	Exposure Pathway	Adult ADD (mg/kg-day)	Adult HQ	Older Child ADD (mg/kg-day)	Older Child HQ	Young Child ADD (mg/kg-day)	Young Child HQ
Spokane River (River-wide)	Sediment	Ingestion	4E-09	0.0002	7E-09	0.0004	4E-08	0.0008
		Dermal	1E-08	0.0007	5E-08	0.002	6E-08	0.001
	Surface Water	Ingestion	6E-12	0.0000003	2E-11	0.0000008	3E-11	0.0000005
		Dermal	5E-09	0.0002	5E-09	0.0003	7E-09	0.0001
	Total HI			**0.001**		**0.003**		**0.002**
Post Falls Dam to Upriver Dam	Sediment	Ingestion	5E-09	0.0002	8E-09	0.0004	4E-08	0.001
		Dermal	1E-08	0.0007	5E-08	0.003	6E-08	0.001
	Surface Water	Ingestion	2E-11	0.000001	4E-11	0.000002	7E-11	0.000001
		Dermal	1E-08	0.0007	2E-08	0.0008	2E-08	0.0004
	Total HI			**0.002**		**0.004**		**0.003**
Upriver Dam to Nine Mile Dam	Sediment	Ingestion	6E-09	0.0003	1E-08	0.0005	6E-08	0.001
		Dermal	2E-08	0.0010	7E-08	0.003	8E-08	0.002
	Surface Water	Ingestion	8E-12	0.0000004	2E-11	0.000001	3E-11	0.000001
		Dermal	6E-09	0.0003	7E-09	0.0004	1E-08	0.0002
	Total HI			**0.002**		**0.004**		**0.003**
Nine Mile Dam to Long Lake Dam	Sediment	Ingestion	6E-09	0.0003	9E-09	0.0005	5E-08	0.001
		Dermal	2E-08	0.001	6E-08	0.003	8E-08	0.002
	Surface Water	Ingestion	8E-12	0.0000004	2E-11	0.000001	3E-11	0.000001
		Dermal	6E-09	0.0003	7E-09	0.0004	1E-08	0.0002
	Total HI			**0.001**		**0.004**		**0.003**
Long Lake Dam to Lake Roosevelt	Sediment	Ingestion	1E-09	0.0001	2E-09	0.0001	1E-08	0.0002
		Dermal	4E-09	0.0002	1E-08	0.0007	2E-08	0.0004
	Surface Water	Ingestion	1E-12	0.0000000	3E-12	0.0000001	4E-12	0.0000001
		Dermal	8E-10	0.00004	9E-10	0.00005	1E-09	0.00002
	Total HI			**0.0003**		**0.001**		**0.001**

Notes:
ADD = average daily dose
HI = hazard index
HQ = hazard quotient

Table 4-15. Hypothetical Noncancer Risks Associated with Water Recreation

River Area	Exposure Medium	Exposure Pathway	Adult ADD (mg/kg-day)	Adult HQ	Older Child ADD (mg/kg-day)	Older Child HQ	Young Child ADD (mg/kg-day)	Young Child HQ
Spokane River (River-wide)	Sediment	Ingestion	2E-09	0.0001	4E-09	0.0002	2E-08	0.0004
		Dermal	7E-09	0.0003	1E-08	0.0007	2E-08	0.0004
	Surface Water	Ingestion	9E-12	0.0000004	1E-11	0.0000007	4E-11	0.0000008
		Dermal	3E-09	0.0001	3E-09	0.0002	4E-09	0.0001
	Total HI			**0.0006**		**0.001**		**0.0008**
Post Falls Dam to Upriver Dam	Sediment	Ingestion	3E-09	0.0001	4E-09	0.0002	2E-08	0.0004
		Dermal	8E-09	0.0004	2E-08	0.0008	2E-08	0.0004
	Surface Water	Ingestion	3E-11	0.000001	4E-11	0.000002	1E-10	0.000002
		Dermal	8E-09	0.0004	9E-09	0.0004	1E-08	0.0002
	Total HI			**0.001**		**0.001**		**0.001**
Upriver Dam to Nine Mile Dam	Sediment	Ingestion	3E-09	0.0002	5E-09	0.0003	3E-08	0.0006
		Dermal	1E-08	0.0005	2E-08	0.001	3E-08	0.0005
	Surface Water	Ingestion	1E-11	0.000001	2E-11	0.000001	5E-11	0.000001
		Dermal	4E-09	0.0002	4E-09	0.0002	5E-09	0.0001
	Total HI			**0.001**		**0.001**		**0.001**
Nine Mile Dam to Long Lake Dam	Sediment	Ingestion	3E-09	0.0002	5E-09	0.0002	3E-08	0.0005
		Dermal	9E-09	0.0005	2E-08	0.0009	2E-08	0.0005
	Surface Water	Ingestion	1E-11	0.000001	2E-11	0.000001	5E-11	0.000001
		Dermal	3E-09	0.0002	4E-09	0.0002	5E-09	0.0001
	Total HI			**0.001**		**0.001**		**0.001**
Long Lake Dam to Lake Roosevelt	Sediment	Ingestion	7E-10	0.00004	1E-09	0.0001	6E-09	0.0001
		Dermal	2E-09	0.0001	4E-09	0.0002	6E-09	0.0001
	Surface Water	Ingestion	1E-12	0.0000001	2E-12	0.0000001	6E-12	0.0000001
		Dermal	4E-10	0.00002	5E-10	0.00003	7E-10	0.00001
	Total HI			**0.0002**		**0.0003**		**0.0003**

Notes:
ADD = average daily dose
HI = hazard index
HQ = hazard quotient

Table 4-16. Hypothetical Noncancer Risks Associated with Recreational Fishing[a]

River Area	Exposure Medium	Exposure Pathway	Adult ADD (mg/kg-day)	Adult HQ	Older Child ADD (mg/kg-day)	Older Child HQ
Spokane River (River-wide)	Sediment	Ingestion	1E-09	0.00006	2E-09	0.0001
		Dermal	2E-09	0.0001	3E-09	0.0002
	Surface Water	Dermal	1E-09	0.00006	1E-09	0.00007
	Total HI			**0.0002**		**0.0003**
Post Falls Dam to Upriver Dam	Sediment	Ingestion	1E-09	0.0001	2E-09	0.0001
		Dermal	3E-09	0.0001	3E-09	0.0002
	Surface Water	Dermal	4E-09	0.0002	4E-09	0.0002
	Total HI			**0.0004**		**0.0005**
Upriver Dam to Nine Mile Dam	Sediment	Ingestion	2E-09	0.0001	3E-09	0.0001
		Dermal	4E-09	0.0002	5E-09	0.0002
	Surface Water	Dermal	2E-09	0.0001	2E-09	0.0001
	Total HI			**0.0003**		**0.0005**
Nine Mile Dam to Long Lake Dam	Sediment	Ingestion	1E-09	0.0001	2E-09	0.0001
		Dermal	3E-09	0.0002	4E-09	0.0002
	Surface Water	Dermal	2E-09	0.0001	2E-09	0.0001
	Total HI			**0.0003**		**0.0004**
Long Lake Dam to Lake Roosevelt	Sediment	Ingestion	4E-10	0.00002	6E-10	0.00003
		Dermal	8E-10	0.00004	1E-09	0.0001
	Surface Water	Dermal	2E-10	0.00001	2E-10	0.00001
	Total HI			**0.0001**		**0.0001**

Notes:

ADD = average daily dose

HI = hazard index

HQ = hazard quotient

[a] Only the older child and adult were evaluated for recreational fishing; the young child is less likely to fish (see text for further explanation).

Table 4-17. Hypothetical Noncancer Hazards and Cancer Risks Associated with Exposure to Total PCBs in Spokane River Gamefish

	Noncancer Risk		Cancer Risk	
River Area / Statistic	Child Only	Adult Only	Adult Only	Lifetime
Spokane River (River-wide) plus Lake Roosevelt				
Mean	0.1	0.09	7E-07	9E-07
Median	0	0.02	1E-07	2E-07
90th Percentile	0.2	0.2	1E-06	2E-06
95th Percentile	0.4	0.4	3E-06	3E-06
Post Falls Dam to Upriver Dam				
Mean	0.2	0.1	--	1E-06
Median	0	0.04	--	4E-07
90th Percentile	0.3	0.3	--	3E-06
95th Percentile	0.7	0.5	--	5E-06
Upriver Dam to Nine Mile Dam				
Mean	0.2	0.2	--	2E-06
Median	0	0.05	--	5E-07
90th Percentile	0.5	0.4	--	4E-06
95th Percentile	0.9	0.8	--	8E-06
Nine Mile Dam to Long Lake Dam				
Mean	0.3	0.2	--	2E-06
Median	0	0.06	--	6E-07
90th Percentile	0.6	0.5	--	5E-06
95th Percentile	1	0.9	--	8E-06
Long Lake Dam to Lake Roosevelt				
Mean	0.07	0.06	--	5E-07
Median	0	0.01	--	1E-07
90th Percentile	0.1	0.1	--	1E-06
95th Percentile	0.3	0.2	--	2E-06

Note:

All values reported to one significant digit.

-- = not evaluated

Table 5-1. Summary of Recommended Meals per Month by Species and Reach for the Spokane River

Species	Spokane Arm	Little Falls Pool	Upper Lake Spokane	Nine Mile Dam to Upriver Dam	Upriver Dam to Border
Brown Trout (fillet)	4		1[a]		Do not eat as per WDFW[b]
Largescale sucker (whole)	1	4	1[a]	2[a]	
Mountain whitefish (fillet)			2[a]	1[a]	
Northern Pikeminnow (fillet)		4	2		
Rainbow Trout (fillet)	4		4	2[a]	
Common Carp			Do NOT eat (based on PCBs only)		

Sources: WDOH (2019) and McBride (2018)

Notes:

PCB = polychlorinated biphenyl

WDFW = Washington State Department of Fish and Wildlife

[a]Advisories based on PCBs, polybrominated diphenyl ethers (PBDEs), and lead. All others based on PCBs, PBDEs, and mercury.

[b] WDFW has a ban on catching and keeping any fish in this reach due to concerns over impacts to sensitive fish populations (catch and release only, no bait and single barbless hooks). It supersedes any contaminant-based advisory (McBride 2018).

Table 5-2. Site-Specific Fish Tissue Targets

Target Fish Tissue Concentration	IR_{tissue} (g/day)[a]	Total PCBs Concentration (ppb_{ww})[b]	IR_{tissue} Source	Notes[c]
At Sunding Mean	4.4	522	Sunding (2019)	Mean IR_{tissue}; one meal approximately every 7 weeks
At Sunding 90th percentile	10	226	Sunding (2019)	90th percentile IR_{tissue}; one meal approximately every 4 weeks
At Sunding 95th percentile	17	136	Sunding (2019)	95th percentile IR_{tissue}; one meal approximately every 2 weeks

Notes:

IR_{tissue} = ingestion rate of fish tissue

PCB = polychlorinated biphenyl

ppb_{ww} = parts per billion wet weight

WDOH = Washington State Department of Health

[a] The fish consumption rates are from Sunding (2019).

[b] The calculation of targets follow WDOH guidance on risk-based assessment for fish advisories, but incorporates a 30% cooking loss and an 80 kg body weight to be consistent with the risk assessment (see Section 4.3).

[c] A fish meal size of 8 oz was utilized.

Table 5-3. Species Preference Weighted Average Total PCBs Concentrations in PRA Gamefish Collected from the Spokane River and Lake Roosevelt

Sportfish Group	Number of Detected Samples[a]	Mean Total PCBs Concentration (ppb_{ww})[a]	Species Preference[b] (%)
River-Wide + Lake Roosevelt			
All Fish	111/122	64.3	(see below)
Bass Group	15/16	52.8	7.1%
Perch Group	0/6	5.33	0.37%
Salmon Group	36/37	122	6.3%
Trout Group	54/57	42.9	35%
Walleye Group	6/6	3.9	51%
Species Preference Weighted Mean		28.7	100%
Post Falls Dam to Upriver Dam			
All Fish	8/8	42.4	(see below)
Bass Group	--	--	--
Perch Group	--	--	--
Salmon Group	--	--	--
Trout Group	8/8	42.4	100%
Walleye Group	--	--	--
Species Preference Weighted Mean		42.4	100%
Upriver Dam to Nine Mile Dam			
All Fish	54/54	87.1	(see below)
Bass Group	--	--	--
Perch Group	--	--	--
Salmon Group	18/18	163	15%
Trout Group	36/36	49.3	85%
Walleye Group	--	--	--
Species Preference Weighted Mean		66.3	100%
Nine Mile Dam to Long Lake Dam			
All Fish	35/43	60.9	(see below)
Bass Group	15/16	52.8	14%
Perch Group	0/6	5.33	0.75%
Salmon Group	18/19	83.0	13%
Trout Group	2/2	83.5	72%
Walleye Group	--	--	--
Species Preference Weighted Mean		78.4	100%
Long Lake Dam to Lake Roosevelt			
All Fish	3/6	21.3	(see below)
Bass Group	--	--	--
Perch Group	--	--	--
Salmon Group	--	--	--
Trout Group	3/6	21.3	100%
Walleye Group	--	--	--
Species Preference Weighted Mean		21.3	100%

Notes:

-- = no data available for species group

PCB = polychlorinated biphenyl

ppb_{ww} = parts per billion wet weight

[a] Values are half-detection limit arithmetic means from Table 4-9, except for the perch group, where data were all non-detects so summary statistics are not reported in Table 4-9. Perch group means were calculated from raw data (Appendix B, Table 4-Bc).

[b] Species preferences are based Sunding (2019).

Table 6-1. Reanalysis of Gamefish Fillets Weighted Mean Total PCBs Concentrations[a] from WDOH (2011)

Approach	Species	Sample Station	No. Samples	Detection Frequency	Mean Total PCBs (ppb_{ww})[b]	Max of Stations
WDOH (2011)	Brown trout	Spokane River (River Mile 55.2)	1	1/1	130	x
	Mountain whitefish	Spokane River (River Mile 40.1)	6	5/6	75.4	
		Spokane River (River Mile 55.6)	3	3/3	43.1	
		Spokane River (River Mile 64.0)	3	3/3	139	
		Spokane River (River Mile 77.0)	3	3/3	234	x
	Rainbow trout	Spokane River (River Mile 64.0)	3	3/3	72.6	
		Spokane River (River Mile 75.2)	3	3/3	153	x
		Spokane River (River Mile 85.0)	3	3/3	54.9	
	Weighted mean concentration by species,[c] using station-specific maximum means:				162	
River-Wide	Brown trout	All	1	1/1	130	
	Mountain whitefish	All	15	14/15	114	
	Rainbow trout	All	9	9/9	93.5	
	Weighted mean concentration by species,[c] across all sampling stations:				102	

Notes:

x = indicates the (maximum) sample station-specific mean total PCBs concentration that was used to represent the mean total PCBs concentration for this species in the calculation of a weighted mean concentration

PCB = polychlorinated biphenyl

ppb_{ww} = parts per billion wet weight

[a] Fish data used by WDOH (2011) are from the 2005 sampling event. Individual sample results are shown in Appendix B, Table B-4c.

[b] Mean values were calculated by setting non-detect results to one-half their reported detection limits.

[c] Weighting from WDOH (2011) and based on the following assumed variations in fish consumption behaviors: 70 percent for rainbow trout, 15 percent for brown trout, and 15 percent for mountain whitefish.

Table 6-2. Comparison between Approach Used to Develop Fish Advisories in Washington State and the Spokane River Probabilistic Risk Assessment

Topic	Washington State Fish Advisory Methodology	Spokane Probabilistic Risk Assessment Methodology
Objective	Determines need for fish advisory and establishes limits on frequencies of fish meals (meals per week) by species that can be "safely" consumed by public based on generic assumptions applied statewide. Does not calculate potential cancer or non-cancer risks to consumers of gamefish.	Calculates potential cancer and non-cancer risks to consumers of Spokane River gamefish based on site-specific information.
Level of Complexity	Simple, generic analysis.	More refined development of inputs and analysis of risks.
Primary Regulatory Guidance	Not specified but presumably follows EPA guidance related to fish advisories: *Guidance for Assessing Chemical Contaminant Data for Use in Fish Advisories* (USEPA 2000b). Most recent published fish advisory for Spokane River based on this document: *Health Consultation, Evaluation of PCBs, PBDEs and Selected Metals in the Spokane River, Including Long Lake, Spokane, Washington* (WDOH 2007). This was updated in 2019 likely based on evaluation of most recent (2012) fish results.	Follows EPA Superfund Risk Assessment Guidance (key EPA guidance shown below): *Risk Assessment Guidance for Superfund: Volume 3, Part A – Process for Conducting Probabilistic Risk Assessment* (USEPA 2001) *Policy for Use of Probabilistic Analysis in Risk at the U.S. Environmental Protection Agency* (USEPA 1997)
Site-Specificity	Partially site-specific. Uses the most recent site-specific fish concentrations (see below) and default inputs for all other parameters.	Fully site-specific, except for some input assumptions where EPA default values were used (e.g., body weights)
Inputs to Calculations	Based on fixed (discrete) input values for estimating exposures (e.g., consumption rate).	Spokane River PRA accounts for ranges (probability distributions) of input values for risk calculations (e.g., fish consumption rates, gamefish PCB concentrations, body weights) to develop ranges of potential risks to compare to regulatory values.
Receptors	All consumers (for PCBs).	Adults (all ages and genders combined) and children evaluated separately. Spokane River PRA does not differentiate between genders or subgroups due to lack of adequate fish consumption information.

Table 6-2. Comparison between Approach Used to Develop Fish Advisories in Washington State and the Spokane River Probabilistic Risk Assessment

Topic	Washington State Fish Advisory Methodology	Spokane Probabilistic Risk Assessment Methodology
Fish Consumption Information	Uses a fish consumption rate of 42 g/day, described as "average recreational anglers" but value was not reported in cited sources (WDOH 1997; SRHD 1998).	Site-specific gamefish consumption rate. Gamefish consumption rate has units of grams per day (g/day). Based on analysis by Brattle Group of fish consumption survey results for Lake Roosevelt (IEc 2013), adjusted for the differences between the demographic profiles of the counties bounding Lake Roosevelt to those from Spokane River.
Fish Species Consumption Preferences	Does not account for angler preferences for collection and consumption by fish species.	Accounts for angler preferences for collection and consumption by fish species or gamefish groups (e.g., trout species) as input into the PRA exposure calculations.
Fish Concentrations	2019 fish consumption advisory update based on mean 2012 fish data.	The Spokane River PRA used a larger fish data set than was used by WDOH to develop the fish advisory. Exposures based on individual sportfish species or species groups total PCBs results for samples collected in 2001, 2003, 2005, and 2012. Use of the individual fish results provides a better representation of full range of potential exposures.
Cancer Slope Factor	Cancer slope factor of 2.0 $(mg/kg\text{-}day)^{-1}$	Cancer slope factor of 2.0 $(mg/kg\text{-}day)^{-1}$
Non-Cancer Reference Dose	Non-cancer oral chronic reference dose of $2x10^{-5}$ mg/kg-day	Non-cancer oral chronic reference dose of $2x10^{-5}$ mg/kg-day Non-cancer oral subchronic reference dose of $5x10^{-5}$ mg/kg-day (children only)
Comparison Values	**Non-cancer effects:** Back-calculates acceptable meal sizes from default exposure assumptions, non-cancer oral reference dose shown above, and assumes an acceptable non-cancer risk of 1.	**Non-cancer effects:** Uses chronic reference dose for adult and subchronic oral reference dose for child shown above and exposure inputs to calculate potential non-cancer risks, which are compared to non-cancer risk of 1.
	Cancer effects: Uses cancer slope factor shown above and exposure inputs to calculate potential cancer risks, which are compared to EPA cancer risks of 1 in 10,000 to 1 in 1,000,000.	**Cancer effects:** Uses cancer slope factor shown above and exposure inputs to calculate potential cancer risks, which are compared to EPA cancer risks of 1 in 10,000 to 1 in 1,000,000.

Notes:
EPA = U.S. Environmental Protection Agency
PCB = polychlorinated biphenyl
PRA = probabalistic risk assessment
WDOH = Washington State Department of Health

APPENDIX A

CURRICULUM VITAE OF RUSSELL E. KEENAN, PH.D.

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PROFESSIONAL PROFILE

Dr. Russell Keenan is a vice president and principal toxicologist at Integral Consulting with 30 years of experience specializing in chemical risk assessment and toxicology. Much of his work focuses on assessing the potential human health and ecological risks of PCBs, dioxins, furans, mercury, copper, and chromium, and on developing time-dependent probabilistic risk assessment methods. Over the past 30 years, he has directed a team of scientists in evaluating the human health and ecological risks associated with chemical exposures at a number of sites involving multiple exposure pathways. Many of the more complex sites are associated with aquatic environments, including the Hudson, Housatonic, Fox, Penobscot, Woonasquatucket, Columbia, Hackensack, and Passaic rivers. Dr. Keenan has conducted more than 200 human health and wildlife risk assessments for regulated sites and has evaluated risks associated with exposure to conventional and radioactive residuals from former mining operations. He represents clients on multi-stakeholder technical and steering committees; provides technical expertise and support in regulatory negotiations; and provides strategic consultation on CERCLA and RCRA risks, liability issues, and remedy selection.

Dr. Keenan has testified as an expert in several U.S. District Court jurisdictions and before U.S. Congressional panels and state and federal agencies during regulatory proceedings on environmental issues. Among other accomplishments, this work has led to the establishment of EPA-approved alternative ambient water quality criteria in nine states. He served as co-investigator of state and regional angler surveys used by EPA as key studies in evaluating exposures through fish ingestion. Dr. Keenan also managed the first private sector Cooperative Research and Development Agreement with EPA in the field of regulatory toxicology and risk assessment, which developed probabilistic models for characterizing the uncertainty in reference dose estimates used in noncancer risk assessment. Subsequently, he served as one of eight independent experts in the congressionally mandated review of EPA's process for handling toxicological uncertainty in its Integrated Risk Information System (IRIS). He has also served on chemical-specific expert review panels for the nonprofit organization Toxicology Excellence for Risk Assessment (TERA). Dr. Keenan has authored more than 90 publications in his field. He is an active member in the Society of Toxicology, from which he received two best paper awards; serves on the Advisory Board to the Association for Environmental Health and Sciences Foundation; and is a member of the Society for Risk Analysis.

Credentials and Professional Honors

Ph.D., Environmental Biology, Duke University, Durham, North Carolina, 1983
B.S., Biology, Bates College, Lewiston, Maine, 1975

Society of Toxicology, Award for the Outstanding Published Paper in Risk Assessment in 1997
Society of Toxicology, Award for the Outstanding Presented Paper in Risk Assessment at the 1996 Annual Meeting
Technical Association of the Pulp and Paper Industry (TAPPI), Russell O. Blosser Memorial Award for the Best Paper Presented at the 1991 Environmental Conference
Sandoz Corporation, Board of Directors Award for Outstanding Technical Excellence in Environmental Science, 1990

Professional Affiliations

Member of Society of Toxicology
Member, Advisory Board, Association for Environmental Health and Sciences Foundation
Member of the Society for Risk Analysis

Expert Services

San Diego Bay, California—On behalf of Monsanto Company, Solutia Inc., and Pharmacia LLC, authored an expert report (May 9, 2019) and provided expert testimony in deposition (June 27, 2019) on my site-specific risk assessment, evaluation of fish advisories, and evaluation of the safety of residential and all common, real-world recreational uses of San Diego Bay. (*City of San Diego v. Monsanto Company, Solutia Inc., and Pharmacia LLC*, Case No. 15-cv578-WQH-AGS in the U.S. District Court, Southern District of California)

Penobscot River Human Health Risk, Maine—On behalf of Mallinckrodt U.S., LLC, authored an expert report (May 9, 2019) and an expert rebuttal report (May 24, 2019), and provided expert testimony in deposition (August 20, 2019) on my evaluation of the August 2018 report titled, Penobscot River Risk Assessment and Preliminary Remediation Goal Development, prepared by Amec Foster Wheeler Environment & Infrastructure, Inc. (*Natural Resources Defense Council et al. v. HoltraChem Manufacturing LLC et al.*, Civil No. 1:00-cv-69-JAW in the U.S. District Court, District of Maine)

Centredale Manor Superfund Site, Rhode Island—On behalf of Emhart Industries, Inc. (subsidiary of Stanley, Black and Decker, Inc.), authored a detailed expert report and provided expert testimony in deposition (July 29, 2014) and at trial (October 3 and 4, 2016), concluding that EPA failed to follow applicable regulations, appropriate guidance, and objective science in conducting the baseline human health and ecological risk assessments for dioxin and PCBs at the site. EPA's human health risk estimates are not site-specific and are unrealistic or implausible, while EPA's ecological risk assessment is incomplete and inadequate. EPA's determination of site cleanup is much more stringent than necessary to

assure the protection of human health and the environment and the record of decision (ROD) significantly overstates the need for remedial action and establishes cleanup goals that far exceed those needed to protect human health and ecological resources.

On August 17, 2017, the U.S. District Court ruled in favor of Emhart's challenge to the unilateral administrative order (UAO) to perform the remedial design, remedial action, and operation and maintenance as described in the ROD. The court found that EPA made several decisions that violated CERCLA because they were arbitrary, capricious, or otherwise not in accordance with law. These included classification of groundwater as a potential source of drinking water and portions of the fish consumption human health risk assessment. As a result, Emhart is not required to pay the fines and fees stemming from its non-compliance with the UAO. (*Emhart v. New England Container Company, Inc. et al., Case No. 06-218-S and Emhart v. U.S. Air Force et al.,* Case No. 11-023S, in the U.S. District Court, District of Rhode Island)

PCBs at an Old Industrial Site, Wisconsin—On behalf of SPX Corp., TRC Environmental Corp., and Apollo Dismantling Services, LLC, authored an expert report (November 9, 2017) and an affidavit (December 7, 2017) in support of a summary judgment to dismiss the plaintiffs' federal claims under RCRA and TSCA. Opined that the PCBs found in soil on the plaintiffs' property are not the result of a building demolition project. The Court found in favor of the defendants, stating that the plaintiffs failed to show that the defendants violated the relevant standards under RCRA or TSCA (March 30, 2018). (*William Liebhart and Nancy Liebhart v. SPX Corporation, TRC Environmental Corporation, and Apollo Dismantling Services, Inc.* Case No. 16-cv-700, in the U.S. District Court, Western District of Wisconsin)

Petroleum Refinery, Alaska—On behalf of Williams Alaska Petroleum (Shook, Hardy & Bacon), authored an expert report (December 12, 2016) and an expert rebuttal report (January 27, 2017) on the appropriate toxicity values for use in site-specific risk assessment of sulfolane, a chemical substance without toxicity values on EPA's IRIS database. Provided expert testimony in deposition (March 24, 2017) and at trial (October 21, 2019). (*State of Alaska and City of North Pole v. Williams Alaska Petroleum Inc., The Williams Companies, Inc., Flint Hills Resources Alaska, LLC, and Flint Hills Resources, LLC.*, Case No. 4FA-14-01544CI, in the Superior Court for the State of Alaska Fourth Judicial District Court, Fairbanks)

Penobscot River and Estuary, Maine—On behalf of Mallinckrodt U.S., LLC, authored comprehensive expert and surrebuttal expert reports and provided expert testimony in deposition (February 27, 2014) and at trial (June 20, 23 and 24, 2014) before the U.S. District Court, District of Maine defending against allegations of unacceptable human health risk and significant adverse ecological risk to fish and shellfish populations due to mercury in Maine's lower Penobscot River and estuary. Derived ecologically relevant target tissue and dietary mercury concentrations for fish in the river and estuary. (*Natural Resources Defense Council et al. v. HoltraChem Manufacturing LLC et al.,* Civil No. 1:00-cv-00069-JAW in the U.S. District Court, District of Maine)

PCBs in Escambia Bay, Florida—On behalf of Monsanto, provided expert report and deposition to contest allegations of chemical trespass, nuisance, negligence, and property damage related to potential health effects from PCBs in aquatic biota of Escambia Bay, Florida. Scheduled testimony at trial became unnecessary when the case settled. (*John Allen et al. v. Monsanto et al.*, Case No. 2008 CA 001762, Division B, in the Circuit Court in and for Escambia County, Florida)

Wood Products Facility, Dierks, Arkansas—On behalf of Weyerhaeuser, provided services to defend against allegations of chemical trespass, nuisance, negligence, and property damage involving dioxin releases from Weyerhaeuser's operation of an active wood products facility in Dierks, Arkansas. Provided expert report, rebuttal of plaintiffs' expert reports, hearing demonstratives, trial testimony, and cross examination. The jury returned a verdict in favor of Weyerhaeuser on all seven counts. No compensatory or punitive damages were assessed against the company. (*Rhonda Brasel, Individually and as Next Best Friend and Guardian of Christopher Albright and Nathan K. Thomas, et al. v. Weyerhaeuser Company, et al.*, Case No. 4:07cv4037 in the U.S. District Court, Western District of Arkansas, Texarkana Division)

Chlor-alkali Plant, Orrington, Maine—On behalf of Mallinckrodt, LLC and United States Surgical Corporation, provided expert testimony for an extensive evaluation of four proposed remedial alternatives at the former HoltraChem chlor-alkali plant site in Orrington, Maine, to assess relative effectiveness at protecting human health from risk due to release of residual mercury into the Penobscot River. Provided similar comparative analysis for risks of death, injury, and property damage due to transport of contaminated wastes. Provided expert report, pre-filed direct testimony, pre-filed rebuttal testimony, hearing demonstratives, adjudicatory hearing testimony, and cross examination before the Maine Board of Environmental Protection and intervenors for the case. *(Appeal of Designation of Uncontrolled Hazardous Substance Site and Order Concerning Chlor-alkali Manufacturing Facility, Orrington, Penobscot Co., Maine, Proceeding under MRSA §1365 Uncontrolled Hazardous Substance Sites Law).*

Proposed TMDL for PCBs, San Francisco Bay, California—Authored an expert report and wrote sections of the comprehensive comments submitted by the California Chamber of Commerce and the General Electric Company concerning the California Regional Water Quality Control Board's 2007 proposed total maximum daily load for PCBs in San Francisco Bay.

Penobscot River Human Health Risk, Maine—Provided expert services on behalf of Mallinckrodt, Inc. in a case concerning risks due to consumption of fish containing methylmercury from the Penobscot River. Provided testimony in two oral depositions and testified in U.S. District Court. (*Maine People's Alliance & Natural Resources Defense Council, Inc. v. HoltraChem Manufacturing Company, LLC and Mallinckrodt, Inc.*, Docket No. 00-69-B in U.S. District Court)

Evaluation of Provisional Toxicity Criteria for Perfluorinated Chemicals—Evaluated the scientific basis for provisional toxicity factors for PFCs and provided recommendations, consultation,

and peer review to counsel on behalf of a confidential client. Provided support and evaluation of exposure and toxicity issues and weighed the merits associated with the generation of *de novo* rodent bioassay data.

Personal Injury Lawsuit, Maine—On behalf of Kimberly-Clark Corporation, authored an expert report and was expected to testify at trial. The case was settled before trial. (*Anne Meader, et al. v. Kimberly-Clark, et al.*, Docket No. CV-00-0018, Somerset County [Maine] Superior Court).

PCB Health Risks, Ohio—Authored an expert report on the evaluation of health risks posed by PCBs. The case was settled in the U.S. District Court. (Case No. C-1-00530 in U.S. District Court, Southern District of Ohio, Western Division)

Cement Plant, Kentucky—On behalf of Lafarge North America, Inc., provided expert testimony in deposition and in videotaped testimony used at trial. (*Lafarge North America Inc. v. Natural Resources and Environmental Protection Cabinet, Commonwealth of Kentucky Natural Resources and Environmental Protection*, Cabinet File No.: DAQ-25389-037)

PCB Risks, Indiana—Authored an expert report assessing potential risks from PCBs at a former CBS-Westinghouse facility in a personal injury case. This matter settled before trial. (*Craig Taylor et al. v. CBS Corporation* [now Viacom]).

Post-fire Reentry Criteria, Philadelphia, Pennsylvania—Provided fact and expert testimony in three oral depositions concerning the establishment of risk-based reentry criteria for PCBs, dioxins, and furans following an office building fire at One Meridian Plaza in Philadelphia. Authored an expert report that ascertained safe exposure limits to these compounds and directed a risk assessment that evaluated the hypothetical exposures and associated potential risks under various use scenarios for the building. The case settled before trial. (Kostow & Daar)

Mercury Release Site, Vermont—Provided testimony in expert reports and oral deposition concerning the toxicology of mercury and potential human exposures at a RCRA site where mercury had been released to the environment. The case settled before trial. (Hull, Webber, Reis & Canney)

GE-Pittsfield/Housatonic River Site, Massachusetts—In public testimony before the Housatonic River Risk Assessment Peer Review Panel, presented analysis demonstrating that the application of dioxin toxic equivalency factors to evaluate potential PCB health risks was unnecessary to fully characterize health risks. Finding this presentation "compelling," a majority of the panelists recommended that toxic equivalency factors not be used to assess PCB health risks.

PCB Cancer Risk, Virginia—On behalf of American Chemistry Council (Polychlorinated Biphenyls Panel), Utility Solid Waste Activities Group, and National Electrical Manufacturers Association, conducted analysis and wrote expert report demonstrating that the proposed application of dioxin toxic equivalency factors to evaluate the risks posed by PCB mixtures overpredicts the cancer potency of PCBs by at least an order of magnitude.

Presented findings in public hearing to the EPA Science Advisory Board, Dioxin Reassessment Review, Arlington, Virginia

In public testimony before the Executive Committee of the EPA Science Advisory Board, presented analysis demonstrating that application of dioxin toxic equivalency factors to evaluate the risks posed by PCB Aroclor 1254 overpredicts its cancer potency by at least 30-fold. As a result, the issue as to whether it was appropriate to use the dioxin toxic equivalency method to evaluate the risks posed by PCB mixtures was one of the key questions that was evaluated by the National Academy of Sciences in its review of EPA's Dioxin Reassessment.

Drinking Water Criteria—Wrote expert report evaluating the procedures used to derive human health criteria for the Great Lakes Water Quality Initiative and presented findings to the EPA Science Advisory Board, Drinking Water Committee, Washington, DC.

Cancer Slope Factor for PCB Mixtures—Conducted the cancer dose-response assessment, wrote expert report, and provided expert opinion for a successful petition by the General Electric Company to revise the cancer slope factor for PCB mixtures.

Federal Rulemaking for Dioxin-like Compounds—On behalf of the American Forest and Paper Association, prepared expert testimony for EPA hearing on estimating exposure to dioxin-like compounds and on evaluating methods of environmental transport and resulting exposures. In its subsequent consensus report, the hearing panel adopted many of the criticisms to the proposed rule and appended the comprehensive expert report to the text of its findings.

Water Quality Criteria—On behalf of the National Council of the Paper Industry for Air and Stream Improvement, wrote expert report evaluating the procedures used to derive human health and wildlife criteria for the Great Lakes Water Quality Initiative. Presented findings at public hearing held by the EPA Science Advisory Board, Great Lakes Water Quality Subcommittee, Chicago, Illinois.

Fish Consumption Study, Maine—Directed a study and provided regulatory testimony and comments concerning consumption of freshwater fish by Maine anglers and a pathway-specific description of bioaccumulation of dioxin-like compounds from multiple sources. (*Pierce Atwood*)

NPDES Permit Limits, Mississippi—Provided expert testimony in adjudicatory hearing before the Mississippi Department of Environmental Quality regarding NPDES permit limits for Leaf River Forest Products, Jackson, Mississippi.

Land Application of Paper Mill Sludge—On behalf of the National Council of the Paper Industry for Air and Stream Improvement, testified at in public hearing before EPA regarding a proposed rule for the land application of sludge from pulp and paper mills using chlorine and chlorine-derivative bleaching processes. (EPA TSCA Docket No. OPTS-62100; 56 FR 21802).

Personal Injury Litigation Support—Directed confidential client's scientific defense of the personal injury claims related to plaintiffs' alleged exposure to dioxins and furans in wastewater effluent.

James River Old Town Mill, Old Town, Maine—Provided expert testimony in public hearing before the Old Town Planning Board on a hazard evaluation of metal and dioxin concentrations in the sludge/ash, lime mud, and leachate at the James River Old Town Mill.

NPDES Waste Discharge Permits, Oregon—Rebutted testimony in adjudicatory hearing before Oregon's Environmental Quality Commission regarding NPDES Waste Discharge Permits 100715 and 100716.

NPDES Permit Limits for Dioxin, Arkansas—On behalf of International Paper Company and Georgia Pacific, provided expert testimony on the carcinogenic dose response of dioxin given in public hearing before the Arkansas Commission of Pollution Control and Ecology regarding NPDES No. AR0001970 Waste Discharge Requirements for International Paper Company and NPDES No. AR0001210 Waste Discharge Requirements for Georgia-Pacific Corporation.

State Water Quality Standards for Dioxin, Multiple States—Provided expert testimony in public hearings before the following regulatory agencies concerning the establishment or refinement of a health-based water quality standard for dioxin:

- Alabama Environmental Management Commission
- Florida Environmental Regulation Commission
- Mississippi Department of Environmental Quality
- South Carolina Water Quality Commission
- North Carolina Environmental Management Commission
- Oregon Environmental Quality Commission
- Washington State Department of Ecology.

Alabama Water Quality Standard for Dioxin—Provided expert testimony in public hearing before the Alabama Environmental Management Commission concerning the establishment of a health-based water quality standard for dioxin.

Florida Water Quality Standard for Dioxin—On behalf of the Florida Pulp and Paper Association, provided expert testimony in public hearing before the State of Florida Environmental Regulation Commission concerning the establishment of a health-based water quality standard for dioxin in Florida.

Mississippi Water Quality Standard for Dioxin—Provided expert testimony in public hearings before the Mississippi Department of Environmental Quality (Starkville and Jackson), concerning the establishment of a health-based water quality standard for dioxin in Mississippi.

South Carolina Water Quality Standard for Dioxin—On behalf of the South Carolina Pulp and Paper Association, presented expert testimony in public hearing before the South Carolina Water Quality Commission (Georgetown, Greenville, and Columbia) concerning the establishment of a health-based water quality standard for dioxin.

North Carolina Water Quality Standard for Dioxin—On behalf of the North Carolina Forest Products Association, provided expert testimony in public hearing before the North Carolina Environmental Management Commission concerning the establishment of a health-based water quality standard for dioxin in North Carolina.

Oregon Water Quality Standard for Dioxin—Provided expert testimony in public hearing before the Oregon Environmental Quality Commission concerning the petition for rule amendment to establish a health-based, water quality standard for 2,3,7,8,-TCDD.

Washington Water Quality Standard for Dioxin, Washington—On behalf of the Northwest Pulp and Paper Association, testified in public hearing before the Washington State Department of Ecology regarding critical factors for establishing an ambient water quality standard for TCDD.

Georgia Water Quality Regulations—Presented expert testimony in public hearing before the Georgia Board of Natural Resources on amendments to Georgia water use classifications and water quality standards.

Maine Water Quality Regulations—Presented testimony in public hearing before the Maine Legislative Committee on Energy and Natural Resources to clarify the process by which the Board of Environmental Protection regulates the discharge of toxic substances to the state's surface waters.

Minnesota Water Quality Standards—Provided expert testimony in public hearing before the Minnesota Pollution Control Agency on proposed revisions to Minnesota water quality standards.

West Virginia Water Quality Standards—Provided expert testimony in public hearing before the West Virginia State Water Resources Board on proposed amendments and revisions to 46 CSR 1 Title 46 Legislative Rule Series 1 requirements governing water quality standards.

Health Effects of TCDD, Arkansas—On behalf of International Paper, presented expert testimony at public hearing before the Arkansas Commission of Pollution Control and Ecology for reevaluation of the tumor histopathology of Kociba et al. (1978)[1] using 1990 criteria: implications for the risk assessment of 2,3,7,8-TCDD using the linearized multistage model.

[1] Kociba, R.J., D.G. Keyes, J.E. Beyer, R.M. Carreon, C.E. Wade, D.A. Dittenber, R.P. Kalnins, L.E. Frauson, C.N. Park, S.D. Barnard, R.A. Hummel, and C.G. Humiston. 1978. Results of a two-year chronic toxicity and oncogenicity study of 2,3,7,8-tetrachlorodibenzo-*p*-dioxin in rats. *Toxicol. Appl. Pharmacol.* 46(2):279-303.

Emissions from Sludge Drying Operations, Wassau Papers, Wisconsin—Presented expert testimony in public hearing before the Wisconsin Department of Natural Resources on evaluation of emissions from proposed sludge drying operation.

Human Exposure to Dioxins, Florida—On behalf of the Florida Pulp and Paper Association, presented expert testimony in public hearing before the State of Florida Department of Environmental Regulation on acceptable levels of human exposure to dioxin.

Public Relations Support, Northwest Pulp and Paper Association, Washington—Participated in a televised Town Hall debate (Channel 2, Portland, Oregon) addressing dioxin risks.

ADDITIONAL TECHNICAL EXPERIENCE

Regulatory Toxicology, Risk Assessment, Exposure Evaluation, and Regulatory Support

Dioxin Reassessment and Implications for PCBs—On behalf of the American Chemistry Council (Polychlorinated Biphenyls Panel), Utility Solid Waste Activities Group, and National Electrical Manufacturers Association, conducted an analysis and authored a paper showing that the proposed application of dioxin toxic equivalency factors to evaluate the risks posed by PCB mixtures overpredicts the cancer potency of PCB Aroclor 1254 by at least 30-fold. Presented these findings in a public hearing to the EPA Science Advisory Board, Dioxin Reassessment Review Committee and again before the Executive Committee of the EPA Science Advisory Board. In collaboration with coworkers, refined the analyses, prepared five papers for submission to peer-reviewed journals, and presented these findings to members of the Federal Interagency Work Group charged by the U.S. Congress with reviewing and evaluating the merits of EPA's draft dioxin reassessment. Along with other scientific critiques of the EPA reassessment, these analyses and presentations served as compelling evidence in support of a congressional mandate for a National Academy of Sciences review of the draft dioxin reassessment. (*During the NAS review, Dr. Keenan and Dr. Silkworth of the General Electric Company were invited by NAS to present their research showing that the toxic equivalency approach ignores empirical evidence regarding PCB toxicity and substantially overpredicts risks. Several of their key findings were expressed in the NAS Final Report under the recommendations for revising the dioxin reassessment*.)

Lower Passaic River Superfund Site, New Jersey—Serving as principal-in-charge of the Integral scientific team providing strategic consultation and technical support in human health and ecological risk assessment, conceptual site model development, and remedy selection on behalf of certain parties engaged in the Lower Passaic River Study Area (LPRSA), one of the largest Superfund projects of a contaminated river in the United States. This work includes providing technical support in the development of the human health and ecological risk assessments; guiding the development and assessment of angler survey methods; and reviewing environmental chemistry, toxicity, bioaccumulation, and related test results. Actively participating as a technical lead in LPRSA working groups assigned to explore important risk and liability issues.

Housatonic River and Floodplain, Massachusetts and Connecticut—For more than 15 years, has provided risk assessment, toxicology, and regulatory support related to the Housatonic River and its floodplain in Massachusetts and Connecticut. Evaluated potential risks associated with PCBs in groundwater, subsurface soil, and air in industrial areas and evaluated potential exposures to PCBs in surface soil, sediment, and food products associated with the floodplain of the river. Provided extensive peer review comments and participated in numerous regulatory negotiations associated with selecting and supporting approaches for conducting both the human health and ecological risk assessments for the site. These approaches have included identification of potentially exposed receptors, definition of discrete exposure areas, and selection of potential land uses for evaluation. Designed site-specific studies for the purpose of collecting specific information about the locations and types of recreational activities occurring along the Housatonic River and its floodplain and the fish consumption behaviors of recreational anglers who use it. Applied the microexposure event model to characterize potential risks to fish consumers who might use the site. This work has included interactions and comments with the peer reviewers, exploration of alternative risk assessment approaches, and regulatory negotiations with EPA and the partner agencies.

PCB Risk Assessment for the Hudson River PCB Superfund Site and Development of Alternative Probabilistic Analyses, New York—Critically evaluated the risk assessment of PCB-containing sediments in the Hudson River. During this evaluation, directed the development of a site-specific risk assessment based on regional fish consumption rates and other exposure factors using a microexposure event Monte Carlo analysis. Achieved consensus with EPA and its contractors that a Monte Carlo approach should be used for the Hudson River risk assessment. Through the use of the model, it was possible to characterize the distribution of PCB dose rates in a hypothetical population of recreational anglers who might potentially consume fish in the absence of fish consumption advisories. By more accurately characterizing the potential risks from PCBs in the river, the microexposure event analysis became an important analysis in the selection of remedial alternatives for this site.

Fox River PCB Superfund Site, Wisconsin—On behalf of the Fox River PRPs, provided consultation, third-party review, and analysis of agency and trustee claims on human health, ecological risk, and natural resource damage issues in conjunction with the Fox River PCB investigation and remedial action program. Developed a microexposure event Monte Carlo model for evaluating the potential human health risks associated with ingesting fish from the river and prepared comments for submission to the administrative record. The incorporation of critical site-specific data on exposure and PCB fish trends enhances the precision of the potential cancer and noncancer risk estimates over those predicted by the default human health risk analysis. Analyzed the various remedial alternatives proposed for the Lower Fox River and found that an extensive dredging remedy would not lead to reduced risks compared to an adaptive management approach. Prepared comments for submission to the U.S. Department of the Interior, Fish and Wildlife Service, concerning the *Draft Joint Restoration Plan and Environmental Assessment for the Lower Fox River and Green Bay*.

Centredale Manor–Woonasquatucket River Restoration Project Superfund Site, North Providence, Rhode Island—Led a team in providing human health and ecological risk assessment support, environmental fate and transport consultation, sampling design, data quality assurance, and other support services. The site is associated with potential human health risk issues and ecological concerns from the presence of dioxins, furans, and PCBs in all environmental media, but particularly in aquatic environments, associated biota, and neighboring terrestrial environments. Developed and presented a white paper on assessing and managing human health and ecological risks at contaminated sediment sites to EPA's Contaminated Sediments Technical Advisory Group. Prepared comments to the administrative record on issues related to the fate, transport, and human health and environmental risks associated with the compounds at this complex site. Developed alternative remedial strategies that considered removing the existing dam structures and placing the contaminated sediment in nearshore confined disposal facilities. In support of the "no dam" alternatives, and as part of an EPA consent order, prepared a comparative ecological assessment report that evaluated the current environs and contrasted the structure and function of those environs against others that would exist under the "no dam" alternatives. Investigated the efficacy of the dam-removal options in terms of flood retention, forested wetlands inundation, and riverbed scour potential.

Comprehensive State-wide Fish Consumption Survey, Maine—Directed the development and implementation of a statistically valid statewide survey to assess the rate of freshwater fish consumption by anglers and their families. Coauthored a peer-reviewed journal article presenting the survey methodology and results. The results of this survey provided a full distribution of ingestion rates for use in a Monte Carlo exposure assessment. Performed in cooperation with resource economists at the University of Maine and with representatives of the Maine Department of Inland Fisheries and Wildlife, the Maine Angler Survey became the most definitive study of its type to assess the rate of fish ingestion among freshwater anglers in North America. The Maine Angler Survey was selected as a "Key Study" in EPA's *Exposure Factors Handbook* and is recommended as a basis for the selection of fish consumption rates by freshwater recreational anglers.

EPA, National Center for Environmental Assessment Peer Review—Served as one of eight independent experts selected in the congressionally mandated review of EPA's process for handling toxicological uncertainty in EPA's IRIS listing of chemicals. Evaluated and commented on EPA's characterization of data uncertainty and variability for a subset of IRIS assessments. Results of this peer review were submitted to the EPA Science Advisory Board and to the U.S. Congress.

First EPA Cooperative Research and Development Agreement (CRADA) in Risk Assessment—Established and served as principal investigator for the first CRADA under the Federal Technology and Transfer Act with EPA in the field of risk assessment. This CRADA was established to provide the framework for a cooperative research project between the private sector and EPA to develop Monte Carlo-based models for characterizing the uncertainty in reference dose estimates used in noncancer risk assessment. By reducing uncertainty in the

reference dose, increased confidence can be placed in setting environmental cleanup levels, thus enhancing cost-effective environmental restoration.

Comprehensive Evaluation of the Environmental Aspects of Mercury—Led the proactive research and scientific evaluations of the pulp and paper industry in anticipation of proposed regulatory actions aimed at establishing a zero-discharge limit of elemental mercury to the environment. Headed the team that developed and authored a comprehensive study that included a characterization of the relative contribution of 1) the natural and anthropogenic sources of mercury; 2) current levels in air, surface water, soil, sediment, and biota; 3) potential implications of the Great Lakes Water Quality Initiative and other regulatory programs related to the regulation of mercury in the environment; and 4) an evaluation of inputs and outputs of mercury from various industrial processes at each of the mills and facilities of the trade association's members. As a result of the team identifying how mercury enters the environment, how it cycles through it, and how various changes in certain industrial processes and raw materials can reduce discharges to the environment, voluntary sustainable practices were instituted and the proposed zero-discharge limits were never promulgated.

Comprehensive Ecological Risk Assessment of PCBs in a Floodplain—Developed a comprehensive ecological assessment for evaluating the reproductive success of insectivorous songbirds nesting in the vicinity of a floodplain containing PCBs. This analysis was conducted using "top-down" retrospective techniques in which study area populations were compared to reference populations remote to the influence of PCBs.

Comprehensive Multisite Human Health Risk Assessment of PCBs in a River—Directed a comprehensive multisite human health and ecological risk assessment of the river and its environs under RCRA and a state Superfund program. Evaluated potential exposures to soil, air, sediment, groundwater, and surface water, including the design and implementation of fish consumption, land use, and recreational use surveys. Evaluated the need to implement emergency response measures by directing the development of a property-by-property risk assessment of floodplain land use.

Ecological Risk Assessment for the BROS Superfund Site Located in a Coastal Swamp, New Jersey—Principal-in-charge of an ecological risk assessment of wetland communities, including a red maple swamp impacted by a historical release from an adjoining waste oil lagoon. The risk assessment work plan was prepared in accordance with EPA's ecological risk assessment guidance for Superfund. Principal chemicals of potential ecological concern included PCBs, PAHs, and certain heavy metals. Portions of the swamp are tidally influenced, while other areas are influenced by local hydrology. A wide variety of assessment and measurement endpoints were used, in light of the large areal extent (400+ acres) of the swamp. Receptors included vegetation, small mammals, aquatic birds and raptors, and large mammals. Results were used to support the RI/FS for the site.

Site-specific Human Health and Ecological Risk Assessments of 20 Chromium Sites, New Jersey—Characterized the potential human health and ecological risks associated with exposure to chromite ore processing residue (COPR), which had been used historically to fill wetlands

and low-lying areas in Hudson County, New Jersey. Several of these sites are located in proximity to the Hackensack River, many are currently the location of commercial or industrial enterprises, and a few are residential properties. Prior to conducting the site-specific risk assessments, developed detailed protocols and methods for submission to the New Jersey Department of Environmental Protection. Prepared technical white papers on the following topics: evaluating potential inhalation exposures to COPR, characterizing the risks of allergic contact dermatitis, evaluating nature and extent of deep groundwater contamination, evaluating compliance with ambient surface water quality criteria for hexavalent chromium, and characterizing potential ecological risks from chromium in a heavily industrialized waterway. These white papers were presented verbally and in written form to agency staff, were the subject of monthly meetings and informal discussions with the agency, and helped achieve settlement or closure of several sites.

Human Health Risk Evaluations to Support Alternative Remedies for a Former Uranium Mine, New Mexico—In response to screening-level cleanup options based on an overly prescriptive and precautionary risk assessment, developed a revised risk assessment for radionuclides and non-radionuclides (predominantly metals) based on site-specific and culturally appropriate exposure parameters. These assessments evaluated and compared the residual risks that would likely remain under a number of proposed remedies, with the purpose of demonstrating the health-protectiveness of less costly options. If pertinent to a given remedy, the risk assessments evaluated and compared the relative risks associated with the transportation and disposal of waste materials offsite. Presented a number of these risk-based approaches in meetings on the nature and conduct of the engineering evaluation and cost assessment with EPA and representatives of the Native American nation.

Human and Ecological Risk Evaluations, Former Uranium Mine, Grand Canyon, Arizona—Guided the development of human health and ecological risk assessments designed to target a goal of implementing a cost-effective remedy for a former copper and uranium mine on the rim of the Grand Canyon. Both radionuclides and non-radionuclides (predominantly metals) were included in these assessments. Human health risks from radionuclides were evaluated using the RESRAD model, whereas non-radionuclide health risks, as well as ecological risks, were evaluated in accordance with conventional EPA guidance. Located within a national park, this particular project had the added dimension of multiagency oversight and review, including that of the National Park Service, EPA, and state agencies.

Site-specific Risk Assessment of 1,4-Dioxane and Derivation of Risk-based Concentrations to Support Site Closure, Western U.S.—Conducted a site-specific human health risk assessment and derived risk-based concentrations for 1,4-dioxane to support closure of a groundwater pump-and-treat remediation system at a site in the western U.S., which had already reduced the levels of trichloroethylene and other volatile organic compounds below their respective regulatory criteria. The risk assessment was submitted to EPA and to the

state environmental agency as part of an optimization plan for shutting down the remediation system.

Health-based Remediation Plan—Selected a health-based remedial option and negotiated a remediation plan with an EPA regional office for a hazardous waste site. The plan was based on a risk assessment of groundwater and industrial soils contaminated with PCBs, dioxins, furans, and chlorobenzenes from leaking electrical transformers. The results of the risk assessment were used as the basis for establishing cleanup criteria at the facility.

Remedial Investigation Endangerment Assessment of PCB-Contaminated Site, Pennsylvania—Managed a remedial investigation endangerment assessment of a PCB-contaminated railyard and drainage basin. This assessment was prepared on behalf of the PRPs under a consent decree with EPA Region 3 and the Pennsylvania Department of Natural Resources.

Development of Alternative Ambient Water Quality Standards for Dioxin, Various States—Developed the basis for establishing alternative ambient water quality standards for dioxin in eight states, receiving state and EPA approval. Submitted and presented these analyses before various state and federal regulatory agencies for the purpose of negotiating scientifically defensible effluent limits. Testified as an expert witness in regulatory hearings and adjudicatory proceedings in 10 states.

Dioxin and Furan Risk Assessments for Numerous Pulp and Paper Companies—Represented numerous pulp and paper companies in addressing the risks associated with dioxins and furans. Presented testimony on the hazards posed by dioxins to a congressional subcommittee and before the U.S. Congress Office of Technology Assessment. Conducted the most comprehensive risk assessment to date of the hazards posed by trace levels of dioxins and furans in paper products. U.S. and Canadian federal agencies used these assessments as the basis for concluding that health risks were *de minimis* and that these products did not require further regulation.

Risk Assessment of Dioxins and Furans in Wastewater Treatment Plant Sludge—Directed the most comprehensive set of published risk assessments on the hazards posed to humans and wildlife by dioxins and furans in wastewater treatment plant sludge applied to farmland, forestland, and abandoned strip mine sites. Testified as an expert witness in regulatory proceedings at the state and federal level. Assessments have resulted in establishment of the first state dioxin standard for agricultural soils and agency approval of permit applications for land application of sludge and residuals in a number of states.

Evaluation of EPA's Cancer Slope Factor for Dioxin—Evaluated the scientific basis for EPA's cancer slope factor for dioxin by critically examining the rodent bioassay data. Proposed and obtained funding for an independent re-review of the rat liver pathology data through the formation of a pathology working group (PWG) of expert pathologists. Based on the group's results, derived a scientifically defensible cancer slope factor through the use of EPA's own model, resulting in a value 16 times less restrictive, and published this analysis in the peer-reviewed literature.

Risk Assessment Work Plan and Final Report for Stringfellow Superfund Site, Riverside, California—Prepared a work plan and final report for the supplemental human health risk assessment for the Stringfellow Superfund Site in Riverside, California, and negotiated its acceptance with EPA Region 9. This EPA-approved risk assessment included the use of a microexposure Monte Carlo analysis for evaluating potential risk to a changing population based on site demographics. It became the first EPA-approved work plan in Region 9 for a PRP-generated risk assessment after the agency's moratorium was lifted and the first risk assessment to gain EPA Region 9 approval for the use of a Monte Carlo exposure analysis.

Regulatory Review of Proposed Rule Related to Chlorophenols—Analyzed and evaluated the key toxicological and exposure assumptions that formed the basis for an EPA-proposed rule (58 FR 79:25706) under which residuals from the use of certain chlorophenolic formulations in the wood-surface-protection industry would have been classified as hazardous waste under RCRA. As a result, EPA withdrew the proposed rule and decided not to list these chlorophenols as hazardous waste.

Development of Health-based, Risk-driven Remediation Assessments—Conducted and guided the development of health-based, risk-driven remediation assessments for RCRA facility investigations and as part of the RI/FS process at CERCLA sites. Obtained a monitored natural attenuation remedy in the record of decision at the Packaging Corporation of America Superfund Site in Michigan.

Evaluation of Proposed Ecological Criteria/Water Quality/Soil Contaminants—Critically evaluated proposed ecological criteria for the Great Lakes, for the State of New Jersey, for water quality in nine states, and for soil contaminants nationwide. Presented critiques of ecological criteria before state and federal agencies and testified on the issues during federal Toxic Substances Control Act rulemaking hearings.

Critique of Scientific Basis for Proposed Federal Standards—Critiqued and reviewed the scientific basis for proposed federal standards for dioxins and furans in wastewater treatment plant sludges. Provided expert opinion regarding the validity of ecotoxicological and human exposure parameters used by EPA's contractor, negotiated more reasonable values with regulatory agencies, and testified in federal rulemaking proceedings. As a result, EPA withdrew the proposed national rule for landspread sludge.

Consumer Product Risk Assessment for a Paper Company Manufacturing Consumer Products from Excess Paper Fiber—Conducted a quantitative risk assessment to ensure that trace PCBs and dioxins/furans did not pose a health risk to consumers using Consumer Products Safety Commission, Food and Drug Administration, and Occupational Safety and Health Administration exposure protocols.

Development of Sampling Programs to Support Risk Assessments—Guided the development of a statistically valid sampling program for sediment and biota to support a comprehensive risk assessment at a series of hazardous waste sites under state and federal jurisdiction. Directed the development of residential, recreational, occupational, and commercial

exposure scenarios to characterize potential exposures in soil, air, water, and biota. Developed health-based cleanup goals as part of the remediation strategy.

Design of a Statistically Based Fish Sampling Plan—Designed a statistically based fish sampling plan through simulation modeling and predictive methods to ensure an optimal experimental design. Reduced sampling and analytical costs of the proposed plan while maximizing the power of the analysis. Completed this study by conducting the most comprehensive risk assessment to date of dioxin in fish, based on actual measurements of this contaminant in the fish that people are likely to consume.

Risk Assessment for a Terrestrial Wildlife Species—Wrote and published one of the first risk assessments for a terrestrial wildlife species based on scientifically refined exposure parameters and toxicokinetic modeling.

Reinterpretation of Dioxin Bioaccumulation Factors—Analyzed and evaluated reported bioaccumulation factors for dioxin and published a peer-reviewed paper that reinterpreted the wide variation in reported values on a common basis.

Advisor to Industry Association—Served as the toxicologist member of the Scientific Advisory Board to the Cement Kiln Recycling Coalition, the independent blue ribbon panel chosen to evaluate the public health and environmental implications of using waste-derived fuels for producing Portland cement.

Numerous Multipathway Exposure and Risk Assessments—Managed multiple-pathway exposure and risk assessments of emissions from resource recovery facilities; releases from leaking underground petroleum storage tanks; and environmental emissions, effluents, and soil contaminants from chemical manufacturing plants. Evaluated the risks to humans and wildlife from exposure to herbicides used for power line right-of-way maintenance.

Critique of Proposed Ambient Air Level Standards—Critiqued and reviewed the scientific basis of proposed state ambient air level standards for carcinogenic and noncarcinogenic air pollutants. Testified before the state air toxics board regarding this review and the development of ambient air guidelines.

Right-to-Know and Hazard Communication—Implemented right-to-know and hazard communication compliance programs for employers in four northeastern states, including 20 acute-care and rehabilitation hospitals. Conducted hazard communication training for more than 3,000 employees. Also planned, coordinated, and managed regional and international symposia on environmental health-related topics.

Comprehensive Literature Review and Report, Augusta, Maine—Conducted a literature review and authored a comprehensive report on the protection of red spruce from spruce budworm defoliation via chemical and biological methods for Forest Service, Maine Department of Conservation, Augusta, Maine.

Additional Experience

Pesticide Conference Organization—Planned, coordinated, publicized, and managed the North American Conference on Pesticide Spray Drift and Chemical Trespass, an international symposium on the legal, environmental, human health, and technological aspects of off-target pesticide drift for Board of Pesticides Control, Maine Department of Agriculture, Food and Rural Resources, Augusta, Maine. Edited and coordinated publication of the conference proceedings. Abstracted and authored a document that summarized the conference for legislative and regulatory use.

Biomass Harvesting Research and Reporting—Researched, conducted personal interviews, and authored a publication for laypersons about the ecological effects of biomass harvesting in the Maine forest for Maine Audubon Society, Falmouth, Maine.

Program Development for Maine Audubon Society—Developed and managed the environmental resource program at the Maine Audubon Society, including planning, grant procurement, budgeting, and implementation. Analyzed and researched environmental issues. Developed policy positions with trustees and staff; presented Maine Audubon Society’s policies through appointments to statewide advisory boards, working groups, and special committees, and through a program of public education utilizing television, radio, and printed media.

Documentary Television Series on PBS—Wrote, produced, and conducted on-camera interviews for *The Forest: Maine’s Legacy and Future*, a three-part documentary television series on Maine's forest resource with the Maine Public Broadcasting Network; funded in part by the Maine Forest Service, USDA Forest Service, Seven Islands Land Company, Maine Audubon Society, International Paper, Great Northern Nekoosa, and the Sachem Trust.

Gypsy Moth Conference Planning—Planned, organized, and moderated the R.K. Mellon Conference on Chemical Control and Long-term Management of Gypsy Moth, under contract with Yale University; funded in part by the Maine Forest Service, USDA Forest Service, and the Richard K. Mellon Fund.

Public Service Announcements—Wrote three public service announcements, *Bugged by Gypsy Moths*, broadcast in 1982 by WCSH-TV, Portland, Maine.

Wood Energy Publications—Wrote and edited wood energy publications under contract with the U.S. Department of Energy, with partial funding from the Maine Forest Service and the Maine Audubon Society.

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Paustenbach, D.J., J.D. Jernigan, B.L. Finley, S.R. Ripple, and R.E. Keenan. 1990. The current practice of health risk assessment: potential impact on standards for toxic air contaminants. *J. Air Waste Manage.* 40(12):1620-1630.

Wenning, R.J., E.S. Ebert, A.H. Parsons, and R.E. Keenan. 1990. Establishing rational ambient water quality criteria for organic compounds -- the dioxin example. pp. 19-20. In: Proceedings of Sixteenth Annual Maine Biological and Medical Sciences Symposium.

Wenning, R.J., A.H. Parsons, and R.E. Keenan. 1990. Critical factors for establishing ambient water quality standards for TCDD. Abstract #416. Eleventh Annual Meeting of Society of Environmental Toxicology and Chemistry, Washington, DC. November 11-15.

Keenan, R.E., and M.J. Sullivan. 1989. Assessing potential health risks of dioxin in paper products. *Environ. Sci. Technol.* 23:643-644.

Keenan, R.E., M.M. Sauer, and F.H. Lawrence. 1989. Assessment of potential health risks from dermal exposure to dioxin in paper products. *Chemosphere* 19:877-882.

Keenan, R.E., M.M. Sauer, and F.H. Lawrence. 1989. Examination of potential risks from exposure to dioxin in paper mill sludge used to reclaim abandoned Appalachian coal mines. *Chemosphere* 18:1131-1138.

Keenan, R.E., M.M. Sauer, F.H. Lawrence, E.R. Rand, and D.W. Crawford. 1989. Chapter 28: examination of potential risks from exposure to dioxin in sludge used to reclaim abandoned strip mines. pp. 935-998. In: *The Risk Assessment of Environmental and Human Health Hazards: A Textbook of Case Studies*. D.J. Paustenbach (ed.). John Wiley & Sons, New York, NY.

Lawrence, F.H., R.E. Keenan, E.R. Rand, M.M. Sauer, and J.W. Knight. 1989. Uncertainties and conservatism in risk assessment of dioxin in paper mill sludge used for mineland reclamation. pp. 393-396. In: Proceedings of 1989 TAPPI Environmental Conference, Orlando, FL.

Paustenbach, D.J., and R.E. Keenan. 1989. Health risk assessment in the 1990s. *Hazmat World* 44-56.

Keenan, R.E., M.M. Sauer, P.D. Boardman, F.H. Lawrence, and R.S. Gordon. 1988. Assessment of potential health risks to pulp and paper mill workers from dermal exposure to dioxin in bleached pulp, paper and pulp-based products. Technical Bulletin No. 549.58.

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Wenning, R.J., and R.E. Keenan. 1988. Risk driven remediation and the concept of riskopleth development in the assessment of cleanup of contaminated land. pp. 177-178. In: NCASI Special Report 88-01. Proceedings of the 1987 Northeast Regional Meeting of the National Council of the Paper Industry for Air and Stream Improvement, Inc. J.J. McKeown (ed.).

Keenan, R.E., M.M. Sauer, and D.W. Crawford. 1987. Relevant issues in setting sludge utilization regulations. pp. 206-226. In: NCASI Special Report 87-03. Proceedings of the 1986 Northeast Regional Meeting of the National Council of the Paper Industry for Air and Stream Improvement, Inc., New York, NY. J.J. McKeown (ed.).

Keenan, R.E., M.M. Sauer, F.H. Lawrence, and D.W. Crawford. 1987. Assessment of human health risks related to exposure to dioxin from land application of wastewater sludge in Maine. Technical Bulletin No. 525. National Council of the Paper Industry for Air and Stream Improvement, Inc., New York, NY.

Keenan, R.E., M.M. Sauer, F.H. Lawrence, R.S. Gordon, and E.R. Rand. 1987. Assessment of potential health risks from dermal exposure to dioxin in paper products. Technical Bulletin No. 534. National Council of the Paper Industry for Air and Stream Improvement, Inc.

Keenan, R.E. (ed.). 1985. Proceedings and Contributed Papers of the North American Conference on Pesticide Spray Drift and Chemical Trespass. Maine Department of Agriculture, Food and Rural Resources, Augusta, ME.

Keenan, R.E., and M.C. Maritato. 1985. The protection of red spruce from spruce budworm defoliation. Maine Department of Conservation, Augusta, ME.

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Keenan, R.E. 1984. Chips and change in the Maine woods. *Maine Audubon Habitat* 1(6):20-25.

Jennings, D.T., B. Withrow, and R.E. Keenan. 1983. Forest biology research. Miscellaneous Report 281. In: Forest Resources Research Advisory Committee 1982 Annual Report. A.R. Leighton (ed.). University of Maine Life Science and Agriculture Experiment Station.

Keenan, R.E. 1983. The biology of *Phellinus spiculosus* on hickory of the southeastern United States. Ph.D. Dissertation. Duke University, NC.

Keenan, R.E. 1983. Programs presented divergent views of the forest. Bangor Maine Daily News. April 19, 1983. p. 14.

Bessey, E., R.E. Keenan, and R. Wrye. 1982. Formula research. In: Miscellaneous Report 362. Forest Resources Research Advisory Committee 1981 Annual Report. A.R. Leighton, (ed.). University of Maine Life Science and Agriculture Experiment Station.

Keenan, R.E. 1982. Forest insect and disease impact. How can we cope? *Maine Audubon Quarterly* 6(1):6-7.

Keenan, R.E., and E.W. Swain (eds). 1982. Maine firewood study final report 1980-81. Report# ET-15437-T9. U.S. Department Energy, Washington, DC.

SELECTED PRESENTATIONS

Keenan, R.E., and D. Williston. 2018. Plenary Session 4 – Fish consumption rates and data collection. Invited plenary presentation at the Sediment Management Work Group/U.S. Army Corps of Engineers *Workshop on Fish Exposure Processes at Contaminated Sediment Sites*. Vicksburg, MS. May 31.

Keenan, R.E. 2013. Fish consumption rates: the critical factor in assessing human exposure to contaminated sediments. Platform presentation at the Twenty-ninth Annual International Conference on Soils, Sediment, Water and Energy, Amherst, MA. October 22.

Keenan, R.E. and E.S. Ebert. 2012. Overview of human health water quality criteria (HHWQC). Invited presentation at the western regional meeting of the National Council for Air and Stream Improvement, Vancouver, WA, October 1.

Ebert, E.S. and R.E. Keenan. 2012. Fish consumption studies and how the data are used. Invited presentation at the western regional meeting of the National Council for Air and Stream Improvement, Vancouver, WA, October 1.

Keenan, R.E. and E. S. Ebert. 2012. Understanding risk levels used to develop human health water quality criteria. Invited presentation at the western regional meeting of the National Council of Air and Stream Improvement, Vancouver, WA, October 1.

Keenan, R.E., P.O. Gwinn, J.D. Schell, E.A. Carlson and J.B. Silkworth. 2009. Application of nonlinear dose-response methods based on mode of action for polychlorinated biphenyls. Platform presentation at Society of Toxicology (SOT) Annual Meeting. Baltimore, MD. March 17.

Keenan, R.E., P.O. Gwinn, J.D. Schell, E.A. Carlson, and J.B. Silkworth. 2008. Application of nonlinear dose-response methods based on mode of action for PCBs. Platform presentation at Society for Risk Analysis (SRA) Annual Meeting. Boston, MA. December 10.

Keenan, R.E., P.O. Gwinn, J.D. Schell, E.A. Carlson, and J.B. Silkworth. 2008. Application of nonlinear dose-response methods based on mode of action shows reduced cancer risks from PCBs. Platform presentation at Dioxin 2008 – the 28th International Symposium on Halogenated Environmental Organic Pollutants and Persistent Organic Pollutants, Birmingham, UK. August 19.

Keenan, R.E., and E.S. Ebert. 2007. The selection of fish consumption rates as a risk management decision. Poster presentation at EPA 2007 National Forum on Contaminants in Fish. Portland, ME. July 23.

Keenan, R.E., and J.H. Samuelian. 2005. Is TEQ enrichment of PCBs in fish tissue a common phenomenon? Platform presentation at Dioxin 2005 – the 25th International Symposium on Halogenated Environmental Organic Pollutants and Persistent Organic Pollutants, Toronto, Ontario. August 25.

Keenan, R.E., and J.H. Samuelian. 2005. Is TEQ enrichment of PCBs in fish tissue a common phenomenon? – Implications for risk assessment. Poster presentation at EPA 2005 National Forum on Contaminants in Fish. Baltimore, MD. September 19.

Keenan, R.E., J.M. Hamblen, J.B. Silkworth, M.N. Gray, P.O. Gwinn, and S.B. Hamilton. 2004. An empirical evaluation of the cancer potency of dioxin toxic equivalents (TEQs) in four PCB mixtures. Platform presentation at Society of Toxicology (SOT). Baltimore, MD. March 21-35.

Hamblen, J.M., R.E. Keenan, J.B. Silkworth, M.N. Gray, P.O. Gwinn, E.S. Ebert, and S.B. Hamilton. 2003. An empirical evaluation of the potency of dioxin toxic equivalents (TEQs) in PCB mixtures. Poster presentation at 13th Annual Conference of the International Society of Exposure Analysis (ISEA). Stresa, Italy. September 22-26.

Keenan, R.E., J.M. Hamblen, J.B. Silkworth, M.N. Gray, P.O. Gwinn, and S.B. Hamilton. 2003. An empirical evaluation of the potency of dioxin toxic equivalents (TEQs) in several PCB mixtures. Poster presentation at Dioxin 2003 – the 23rd International Symposium on Halogenated Environmental and Persistent Organic Pollutants, Boston, MA. August 24-29.

Swartout, J.C., P.S. Price, S. Baird, H. Carlson-Lynch, M.L. Dourson, R.E. Keenan, C.A. Gillis, C.W. Schmidt, and K. Thompson. 1999. Probabilistic uncertainty in reference doses. Second Annual Workshop on Practical Issues in the Use of Probabilistic Risk Assessment, University of Florida, March 2. Sarasota.

Anderson, P.D., A.L. Nightingale, R.E. Keenan, S. Craig, and J. Patarcity. 1998. Biota to sediment accumulation factors for PAH, metals, and dioxin in two East Coast tidal marshes. Presented at the Thirteenth Annual Hydrocarbon Contaminated Soils Conference, University of Massachusetts, Amherst, MA. October 21.

Price, P.S., and R.E. Keenan. 1998. Advances in non-carcinogenic risk assessment. Toxicology Round Table of the American Crop Protection Association. Seattle, WA. February 28.

Price, P.S., and R.E. Keenan. 1998. Characterizing the RfD/MRL/ADI in a quantitative framework of uncertainty and variability. Annual Meeting of the Society for Risk Analysis, December 7.

Price, P.S., and R.E. Keenan. 1998. Microexposure event modeling an approach to modeling time-varying exposures. New England Chapter – Society for Risk Analysis. Boston, MA. March 11.

Price, P.S., R.E. Keenan, and B.W. Schwab. 1998. Defining the interindividual (intraspecies) uncertainty factor. Third Annual Workshop on Evaluation of Default Safety Factors in Health Risk Assessment, November 11.

Price, P.S., R.E. Keenan, J.A. Rothrock, C.F. Chaisson, D.K. Waylett, M.E. Hawley, C.B. Sandusky, R. Sert, E. DeGraff, W.R. Muir, and J.S. Young. 1998. A case study and presentation of relevant issues on aggregate exposure. ILSI Aggregate Exposure Workshop Program. Washington, DC. February 9-10.

Price, P.S., R.E. Keenan, and S.J. Pauwels. 1998. Using an integrated microexposure event and toxicokinetic model to evaluate the impact of dioxin intakes from the consumption of Maine freshwater fish on angler body burdens. 25th Annual Aquatic Toxicity Workshop. Quebec, Canada, October 21.

Rothrock, J.A., P.S. Price, R.E. Keenan, E.S. Ebert, C.F. Chaisson, W.R. Muir. 1998. The application of microexposure event modeling to the evaluation of water related exposures. Annual Meeting of the Society for Risk Analysis, December 7.

Iannuzzi, T.J., R.E. Keenan, and R.P. Cepko. 1997. Habitat stressors and potential PCB risks to wildlife receptors in Clear Creek, Bloomington, Indiana. SETAC. San Francisco, CA. November 19.

Keenan, R.E., J.A. Rothrock, and P.S. Price. 1997. Should Maine's rivers have fish advisories for dioxin? Society for Risk Analysis/International Society of Exposure Assessment Conference. Washington, DC. December 10.

Keenan, R.E., J.A. Rothrock, and P.S. Price. 1997. Using an integrated microexposure event and toxicokinetic model to evaluate the need for dioxin fish advisories? Society for Risk Analysis Annual Meeting and Exposition. Washington, DC. December 7-10.

Keenan, R.E., and P.S. Price. 1997. FQPA aggregate exposure and common mode of action assessments: new approaches. American Bar Association Section of Natural Resources, Energy, and Environmental Law. Environmental Quality Committee. Washington, DC. September 9.

Keenan, R.E., J.H. Samuelian, T.J. Iannuzzi, S.P. Truchon, and R.P. Cepko. 1997. Calculation of hypothetical PCB risks to wildlife receptors in the Clear Creek Watershed, Bloomington, Indiana. Dioxin 97, Indianapolis, IN. August 24-29.

Keenan, R.E. 1997. Dioxins in the environment: an overview. BFI Organics Dioxin Workshop, Portland, ME. June 6.

Keenan, R.E., and P.S. Price. 1997. Characterizing the uncertainty in the reference dose (RfD). New England Chapter of the Society for Risk Analysis. Cambridge, MA. February 26.

Keenan, R.E., J.A. Stickney, B. Mayes, C.A. Gillis, P.S. Price, and S.B. Hamilton. 1997. Implications of a recent feeding study on the cancer slope factor for PCB mixtures. Platform Presented at the 36th Annual Meeting of the Society of Toxicology (SOT). Cincinnati, OH. March 9-13.

Price, P.S., R.E. Keenan, H. Carlson-Lynch, and C. Gillis. 1997. Defining the interindividual uncertainty factor (UHF): implications for non-cancer dose response

modeling. Society for Risk Analysis/International Society of Exposure Assessment Conference. Washington, DC. December 8.

Ebert, E.S., P.S. Price, and R.E. Keenan. 1996. Estimating exposures to dioxin-like compounds for subsistence anglers in North America. Dioxin 96, Amsterdam, The Netherlands. August 12-16.

Keenan, R.E., E.S. Ebert, and P.S. Price. 1996. Estimating exposures of subsistence anglers. Society for Risk Analysis/International Society of Exposure Assessment Conference (SRA). New Orleans, LA. December 8-12.

Keenan, R.E., N.W. Harrington, P.S. Price, and R.O. Richter. 1996. A comparison of potential risks using default point estimates, Monte Carlo modeling, and microexposure event analysis for evaluating impacted groundwater near the Stringfellow Superfund site. Superfund XVII Conference Proceedings. Washington, DC. October 15-17.

Keenan, R.E., P.S. Price, J. McCrodden, and E.S. Ebert. 1996. Using a microexposure event analyses to model potential exposures to PCBs through ingestion of fish from the Upper Hudson River. Platform Presentation at Dioxin 96 – the 16th International Symposium on Chlorinated Dioxins and Related Compounds, Amsterdam, The Netherlands. August 12-16.

Keenan, R.E., and K.L. Rhyne. 1996. Risk assessment in environmental law. King & Spalding Continuing Education Seminar, Georgia Bar Association, Atlanta. February 23-24.

Maritato, M.C., D.W. Crawford, R.E. Keenan, and S.P. Truchon. 1996. Integrating advanced ecological risk assessment techniques with product life cycle impact assessments. Presented at 17th Annual Meeting of the Society of Environmental Toxicology and Chemistry, Washington, DC. November 17-21.

Price, P.S., and R.E. Keenan. 1996. Characterization of the interindividual (UFH) factor: alternative models and approaches. National Health and Environmental Effects Research Laboratory. September 24-27.

Price, P.S., and R.E. Keenan. 1996. An approach for extrapolating dose rate information from animals to humans. Society for Risk Analysis/International Society of Exposure Assessment Conference (SRA). December 8-12.

Keenan, R E. 1995. Cooperative Research and Development Agreement (CRADA) to estimate noncancer risks from exposure to toxic substances. Presented at EPA Region 1 Seminar on Federal Technology Transfer and Assistance Opportunities, Bath, ME. April 20.

Keenan, R.E. 1995. What is risk? Presented at What You Need To Know About Risk Assessment and Why, Capitol Hill Club, Washington, DC. March 1.

Keenan, R.E., M.H. Henning, J.A. Ducey, and E.S. Ebert. 1995. A field evaluation of the reproductive success of insectivorous passerines inhabiting a flood plain in the presence of PCBs. Presented at the Hydrocarbon Contaminated Soils Conference, New Orleans, LA. January 12.

Keenan, R.E., M.H. Henning, E.S. Ebert, and E.R. Algeo. 1995. Assessment of effects of PCB-contaminated sediments and floodplain soils on reproduction and community structure of insectivorous song birds. Platform presentation at Dioxin '95--15th International Symposium on Chlorinated Dioxins and Related Compounds, Edmonton, Alberta. August 23.

Keenan, R.E., P.S. Price, E.S. Ebert, S.H. Su, and J.R. Harrington. 1995. Uncertainty and variation in indirect exposure assessments: an analysis of exposure to TCDD from a beef consumption pathway. Platform presentation at Dioxin 95--15th International Symposium on Chlorinated Dioxins and Related Compounds, Edmonton, Alberta. August 21.

Keenan, R.E., P.S. Price, C.L. Curry, J.I. McCrodden, and J.G. Haggard. 1995. Using a microexposure Monte Carlo analysis to model potential exposures to PCBs through ingestion of fish from the upper Hudson River. Platform presentation at the Society for Risk Analysis Annual Meeting, Honolulu, HI. December 5.

Keenan, R.E. 1994. Monte Carlo modeling of temporal and spatial variations in exposure. Presented during the Workshop on the Application of Monte Carlo Techniques to Exposure Assessment at the Annual Meeting of the Society for Risk Analysis, Baltimore, MD. December 4.

Keenan, R.E., and P.S. Price. 1994. Development of a Monte Carlo model of uncertainty and variability in reference doses. Poster presentation describing a Cooperative Research and Development Agreement (CRADA) project between McLaren/Hart and the U.S. Environmental Protection Agency. Presented at the Annual Meeting of the Society of Toxicology, Dallas, TX. March 14.

Keenan, R.E, M. Dourson, P.S. Price, J. Swartout, and S.H. Su. 1994. EPA and McLaren/Hart-ChemRisk joint project to develop a stochastic approach for assessing non-carcinogenic risk - A status report. Presented at the Annual Meeting of the Society for Risk Analysis, Baltimore, MD. December 7.

Keenan, R.E., P.S. Price, M.H. Henning, P.E. Goodrum, M.N. Gray, and R.A. Sherer. 1994. Using a microexposure Monte Carlo risk assessment for dioxin in Maine fish to evaluate the need for fish advisories. International Society for Environmental Epidemiology/ International Society for Exposure Assessment Joint Conference, Research Triangle Park, NC. September 18-21.

Keenan, R.E., M.H. Henning, P.E. Goodrum, M.S. Gray, R.A. Sherer, and P.S. Price. 1993. Using a microexposure Monte Carlo risk assessment for dioxin in Maine (USA) fish to evaluate the need for fish advisories. Platform presentation at Dioxin '93 - the Thirteenth International Symposium on Chlorinated Dioxins and Related Compounds. Vienna, Austria. September 21.

Keenan, R.E., P.S. Price, E.S. Ebert, P.E. Goodrum, M.N. Gray, and R.A. Sherer. 1993. A Monte Carlo risk assessment for dioxin in Maine fish: using a microexposure approach to

evaluate the need for fish advisories. 1993 TAPPI Environmental Conference, Boston, MA. March 31.

Keenan, R.E. 1992. Ecological risk assessment in the 1990s. Presented at the First National Conference on Risk Assessment and Community Relations. General Electric Corporate Environmental Programs, Arlington, VA. September 15.

Keenan, R.E. 1992. Estimating exposures to dioxin-like compounds concerning methods of environmental transport and resulting exposures. Presentation at the EPA Peer Review Workshop, Vienna, VA. September 10.

Keenan, R.E. 1992. Concerning an evaluation of the procedures used to derive human health criteria for the Great Lakes Water Quality Initiative. Presentation to the EPA Science Advisory Board, Drinking Water Committee, Washington, DC. April 14.

Keenan, R.E. 1992. Concerning a preliminary evaluation of the procedures used to derive human health and wildlife criteria for the Great Lake Water Quality Initiative. Presentation to the EPA Science Advisory Board, Great Lakes Water Quality Subcommittee, Chicago, IL. February 19.

Keenan, R.E., E.R. Algeo, and J.W. Knight. 1992. Applying ecological risk assessment strategies to address environmental problems. Presented at the Seventh Annual Hydrocarbon Contaminated Soils Conference, University of Massachusetts, Amherst, MA. September 22.

Keenan, R.E., E.R. Algeo, E.S. Ebert, and D.J. Paustenbach. 1992. Taking a risk assessment approach to RCRA corrective action. Presented at the RCRA Corrective Action Workshop, Water Environment Federation, New Orleans, LA. September 20.

Keenan, R.E., E.S. Ebert, J.W. Knight, and N.W. Harrington. 1992. Consumption of freshwater fish by Maine anglers. Contributed paper to 1992 TAPPI Environmental Conference, Richmond, VA. April 15.

Keenan, R.E., E.S. Ebert, J.W. Knight, N.W. Harrington, and N.L. Bonnevie. 1992. Consumption of freshwater fish by Maine anglers. Presented at the Exposure Session during the Thirteenth Annual Meeting, Society of Environmental Toxicology and Chemistry, Cincinnati, OH. November 11.

Sherman, W., and R.E. Keenan. 1992. A pathway-specific description of bioaccumulation from multiple sources: a working hypothesis. Presented at Bioavailability of Dioxin, PCBs, and Metals in Aquatic Ecosystems, 1992 Rifkin Conference, Washington, DC. May 14-15.

Keenan, R.E. 1991. Expert testimony in adjudicatory hearing before the Mississippi Department of Environmental Quality, NPDES Permit Limits for Leaf River Forest Products, Jackson, MS. December 17.

Keenan, R.E. 1991. Presentation to the EPA Peer Review Panel of Risk Assessments for Land Application of Pulp and Paper Mill Sludge, Greenbelt, MD. October 2.

Keenan, R.E. 1991. Ecological risk assessment in the 1990's. Contributed paper to Environmental Remediation from Cradle to Grave: An Engineering Primer for Lawyers and Risk Managers. Armstrong and Teasdale Attorneys at Law, St. Louis, MO. January 25.

Keenan, R.E., E.S. Ebert, D. Gunster, J.W. Knight, E.R. Algeo, M.N. Gray, and N.W. Harrington. 1991. Critical risk assessment factors for establishing a water quality standard for 2,3,7,8-tetrachlorodibenzo-*p*-dioxin. Platform presentation at Dioxin '91 -- the Eleventh International Symposium on Chlorinated Dioxins and Related Compounds, Research Triangle Park, NC. September 26.

Keenan, R.E., R.J. Wenning, E.S. Ebert, J.W. Knight, and C.A. Whitaker. 1991. Critical factors for establishing ambient water quality standards for TCDD. Contributed paper to 1991 TAPPI Environmental Conference, San Antonio, TX. April 10.

Keenan, R.E., E.S. Ebert, E.R. Algeo, M.M. Sauer, J.W. Knight, and R.E. Kross. 1991. A critical evaluation of the EPA risk assessment for pulp and paper mill sludge. Contributed paper to 1991 TAPPI Environmental Conference, San Antonio, TX. April 10.

Keenan, R.E. 1990. A re-evaluation of the tumor histopathology of Kociba et al. (1978) using 1990 criteria: implications for the risk assessment of 2,3,7,8-TCDD using the linearized multistage model. Keynote paper at Dioxin '90 - the Tenth International Symposium on Chlorinated Dioxins and Related Compounds, Bayreuth, West Germany. September 12.

Keenan, R.E. 1990. Dioxin risk assessment for the Columbia River. Contributed paper to Dioxin '90 - Tenth International Symposium on Chlorinated Dioxins and Related Compounds, Bayreuth, West Germany. September 13.

Keenan, R.E. 1990. Setting rational health-based water quality standards for dioxin. Risk assessment for the Columbia River. Contributed paper to 1990 TAPPI Environmental Conference, Seattle, WA. April 11.

Keenan, R.E. 1990. A reevaluation of dioxin cancer potency using the linearized multistage model. Contributed paper to 1990 TAPPI Environmental Conference, Seattle, WA. April 11.

Keenan, R.E. 1990. Examination of potential risks from exposure to dioxin in soils amended with sludge or ash. Presentation at a workshop sponsored by the Maine Department of Environmental Protection and Maine Department of Human Services, Augusta, ME. January 17.

Keenan, R.E. 1990. Establishing a health-based water quality standard for dioxin in Texas. Presentation before the Texas Water Quality Commission, Austin, TX. July 12.

Keenan, R.E., B.L. Finley, and A.H. Parsons. 1990. Criteria for achieving a no-action alternative: a case study. Contributed paper to Haztech International '90, Pittsburgh, PA. October 3.

Keenan, R.E., S.A. Martin, and W.J. Gillespie. 1990. A critical evaluation of the EPA human health and wildlife risk assessment for pulp and paper mill sludge. Presentation to EPA

Office of Toxic Substances, Office of Solid Waste and Environmental Assessment, and Office of Water Programs, Washington, DC. December 12.

Keenan, R.E., N.D. Wilson, and J.W. Knight. 1990. Looking to the 1990's: using risk assessment to design cost-effective solutions to environmental problems. Contributed paper to Haztech International '90, Pittsburgh, PA. October 3.

Keenan, R.E., E.S. Ebert, E.R. Algeo, and M.M. Sauer. 1990. A critical evaluation of the EPA risk assessment for pulp and paper mill sludge. Invited lecture to: Northeast Regional Meeting of the National Council of the Paper Industry for Air and Stream Improvement. Boston, MA. October 25.

Keenan, R.E. 1989. Risk assessment for the Columbia River. Presentation to the Department of Ecology, State of Washington, Department of Environmental Quality - State of Oregon and Environmental Protection Agency Region 10, Portland, OR. December 18.

Keenan, R.E. 1989. Sensitivity analysis for dioxin risk assessment and implications for determining acceptable levels of daily exposure. Presented to the Maine Science Advisory Panel of the Maine Department of Human Services, Augusta, ME. November 17.

Keenan, R.E. 1989. Uncertainties and conservatism in dioxin risk assessment. Contributed paper to 1989 TAPPI Environmental Conference, Orlando, FL. April 19.

Keenan, R.E. 1989. Critical factors for consideration in setting rational health-based water quality criteria for dioxin. Oregon Department of Environmental Quality, Portland, OR. October 27.

Keenan, R.E. 1989. Sources of uncertainty in the carcinogenic dose-response assessment of dioxin. Bureau of Health, Maine Department of Human Services, Augusta, ME. October 12.

Keenan, R.E. 1989. Testimony before the North Carolina Air Toxics Committee regarding the development of ambient air level standards for carcinogenic pollutants, Winston-Salem, NC. January 12.

Keenan, R.E., J.W. Knight, E.R. Rand, and M.M. Sauer. 1989. Assessing potential risks to wildlife and sportsmen from exposure to dioxin in pulp and paper mill sludge spread on managed woodlands. Contributed paper to Dioxin '89 - the Ninth International Symposium on Chlorinated Dioxins and Related Compounds, Toronto, Ontario. September 21.

Keenan, R.E. 1988. The impacts upon human health of trace concentrations of dioxin in pulp and paper mill export vectors. Presentation to community leaders and the press, Escanaba, MI. June 30.

Keenan, R.E. 1988. Risk-driven remediation as an approach for determining cleanup of contaminated land. Presentation at 1988 Groundwater Technology Southcentral Regional Seminar, Baton Rouge, LA. January 20.

Keenan, R.E., M.M. Sauer, and F.H. Lawrence. 1988. Assessment of potential health risks from dermal exposure to dioxin in paper products. Contributed paper to Dioxin '88 - the

Eighth International Symposium on Chlorinated Dioxins and Related Compounds, Umea, Sweden. August 23.

Keenan, R.E. 1987. Examination of potential risks from exposure to dioxin in paper mill sludge used to reclaim abandoned Appalachian coal mines. Contributed paper to Dioxin '87 - the Seventh International Symposium on Chlorinated Dioxins and Related Compounds, Las Vegas, NV. October 8.

Keenan, R.E. 1987. Risk assessment methodology to place levels of dioxin in perspective. Presentation to the Pennsylvania Department of Environmental Resources, Harrisburg, PA. July 9.

Keenan, R.E. 1984. Hazard communication training programs. Massachusetts Right-to-Know Law Seminar, Boston, MA. December 17.

INVITED PRESENTATIONS/PANELS

Invited Presentations

Keenan, R.E., and D. Williston. 2018. Plenary Session 4 – Fish consumption rates and data collection. Invited plenary speaker at the Sediment Management Work Group/U.S. Army Corps of Engineers *Workshop on Fish Exposure Processes at Contaminated Sediment Sites*. Vicksburg, MS. May 31.

Keenan, R.E., and A. Frankel. 2016. Overview of probabilistic risk assessment and decision analysis tools for evaluating environmental issues. Invited presentation at the 32nd Annual International Conference on Soils, Sediment, Water and Energy, Amherst, MA. October 18.

Keenan, R.E., and E.S. Ebert. 2012. Overview of human health water quality criteria (HHWQC). Invited presentation at the western regional meeting of the National Council for Air and Stream Improvement, Vancouver, WA, October 1.

Keenan, R.E. and E. S. Ebert. 2012. Understanding risk levels used to develop human health water quality criteria. Invited presentation at the western regional meeting of the National Council of Air and Stream Improvement, Vancouver, WA, October 1.

Ebert, E.S. and R.E. Keenan. 2012. Fish consumption studies and how the data are used. Invited presentation at the western regional meeting of the National Council for Air and Stream Improvement, Vancouver, WA, October 1.

Keenan, R.E., E.R. Algeo, and P.D. Anderson. 2007. Characterizing and interpreting fish consumption rates for developing human health water quality criteria. Invited speaker to the 2007 West Coast Conference of the National Council for Air and Stream Improvement. Portland, OR. September 26.

Keenan, R.E. 2007. Quantifying interspecies variability in response to direct-acting compounds. Invited speaker to the 2007 EPA Toxicology and Risk Assessment Conference, Cincinnati, OH. April 24.

Keenan, R.E., and J.B. Silkworth. 2005. The TEQ approach ignores empirical evidence regarding PCB toxicity and substantially over-predicts risks. Invited speaker to the National Academy of Science, Third Meeting of the Committee on EPA's Exposure and Human Health Reassessment of TCDD and Related Compounds, Washington, DC. March 21.

Keenan, R.E., E.S. Ebert, and M.H. Henning. 2004. Principle or Practice? That is the question: perspectives of practitioners in private practice. Invited platform presentation at Society for Risk Analysis (SRA) Annual Meeting. Palm Springs, CA. December 6.

Keenan, R.E., and J.J. Loureiro. 2004. Selecting site-specific sediment management approaches to reduce human health and ecological risks. Invited speaker to the Centredale Manor Superfund Site Contaminated Sediments Technical Advisory Group of EPA. Providence, RI. July 15.

Keenan, R.E., P.O. Gwinn, and M.C. Maritato. 2003. The potential impact of hormesis on risk assessment. Invited Platform Presentation at Non-linear Dose-Response Relationships in Biology, Toxicology and Medicine–An International Conference. University of Massachusetts, Amherst, MA. May 28.

Keenan, R.E. 2002. Mercury – An overview about its effects on us and the environment. Dinner lecture to Greater Portland Dental Society Meeting, Portland, ME. September 19.

Keenan, R.E. 2000. Applying dioxin TEQs for PCBs. Presentation of comments on behalf of the Polychlorinated Biphenyls Panel of the American Chemistry Council, the Utility Solid Waste Activities Group, and the National Electrical Manufacturers Association to the EPA Science Advisory Board, Dioxin Reassessment Review, Arlington, VA. November 1.

Keenan, R.E., and P.S. Price. 1999. Tricks of the trade: principles of good practice in probabilistic risk assessment. Invited speaker at Second Annual Workshop on Practical Issues in the Use of Probabilistic Risk Assessment, University of Florida, Sarasota. March 1.

Keenan, R.E., J.D. Avantaggio, and P.S. Price. 1997. Should Maine's rivers have fish advisories for dioxin? Using an integrated microexposure event and toxicokinetic model to evaluate this question. Invited keynote presentation at SETAC North Atlantic Chapter Annual Conference. Portland, Maine. June 13-14.

Keenan, R.E. 1993. Exposure assessment: then and now and quantum leaps in the future. Invited presentation at Conference on the Risk Assessment Paradigm after Ten Years: Policy and Practice Then, Now, and in the Future. Sponsored by EPA, Naval Medical Research Institute, U.S. Army Biomedical Research, and Armstrong Laboratory, Dayton, OH. April 5.

Keenan, R.E., E.R. Algeo, E.S. Ebert, and D.J. Paustenbach. 1993. Taking a risk assessment approach to RCRA corrective action. Invited presentation at The Development of Soil, Sediment, and Groundwater Cleanup Standards for Contaminated Sites -- How Clean is Clean? Water Environment Federation, U.S. Environmental Protection Agency, and Agency for Toxic Substances and Disease Registry, Washington, DC. January 12.

Keenan, R.E. 1991. Applying the strategy of risk assessment to address environmental problems. Keynote address to 1991 Annual Meeting of the First Tier Association of Railroad Environmental Attorneys, Jacksonville, FL. March 25.

Keenan, R.E. 1991. Applying the strategy of risk assessment to address environmental problems. Guest lecture to the Graduate Program in Toxicology and Public Health, University of Massachusetts. Amherst, MA. April 1.

Keenan, R.E. 1991. Issues in dioxin risk assessment. Presentation given at Seminar on Nuisance and Toxic Tort Litigation in the Paper Industry, Simpson Thacher & Bartlett, New York, NY. February 6.

Keenan, R.E. 1991. Reevaluating the cancer potency of dioxin for regulatory purposes. Presentation to the Minnesota Pollution Control Agency and the Minnesota Department of Health, St. Paul, MN. January 10.

Keenan, R.E., and D.J. Paustenbach. 1991. The use and misuse of risk assessment to address environmental problems. Dinner lecture to 1991 Mobil Oil Corporation Environmental Awareness Conference, Fairfax, VA. June 4.

Keenan, R.E., and D.J. Paustenbach. 1991. The application and use of health risk assessment to address environmental problems. Invited paper to the Forum on Emerging Process Technologies, Sandoz Corporation, Glasgow, Scotland. November 18.

Keenan, R.E., A.H. Parsons, E.S. Ebert, and J.W. Knight. 1991. Critical factors for establishing an ambient water quality standard for TCDD in the State of Washington. Presented before the Department of Ecology for the State of Washington and the Environmental Managers and Legal Counsel for the Member Mills of the Northwest Pulp and Paper Association, Seattle, WA. May 21.

Keenan, R.E. 1990. Critical factors for establishing ambient water quality standards for TCDD. Invited lecture to Dioxin in Maine's Rivers: A Symposium. Bowdoin College, Brunswick, ME. December 1.

Keenan, R.E., N.D. Wilson, and J.W. Knight. 1990. Looking to the 1990's: using risk assessment to design cost-effective solutions to environmental problems. Invited lecture to 1990 TAPPI New England Annual Meeting, Harwichport, MA. June 15.

Keenan, R.E. 1990. Risk assessment for the Columbia River. Presentation to Department of Ecology - State of Washington and Department of Environmental Protection. State of Oregon. Prepared by Oregon EPA and the Northwest Pulp and Paper Association, April 16-20.

Keenan, R.E. 1990. Dioxin--What are the risks? Town Hall TV Debate, Channel 2, Portland, OR. March 4.

Keenan, R.E., W.R. Brown, and A.H. Parsons. 1990. An update of the scientific information critical to the establishment of state water quality standards. Presentation to U.S. Environmental Protection Agency, Region VI, Dallas, TX. October 26.

Keenan, R.E., R.J. Wenning, and A.H. Parsons. 1990. A reevaluation of the cancer potency of 2,3,7,8-TCDD and determination of health-protective exposure levels. Invited lecture to Northeast Regional Meeting of the National Council of the Paper Industry for Air and Stream Improvement. Boston, MA. October 25.

Keenan, R.E., J. Graham, A. Finkel, A. Smith, and R. Frakes. 1990. Invited Panelist, Workshop on Considerations in Risk Level Decision Making. Maine Department of Environmental Protection, Augusta, ME. September 20.

Keenan, R.E. 1989. Potential hazards posed by run-off containing TCDD-contaminated soil. Invited lecture to Dioxin in Dirt--Does 1 ppb Make Sense? Resources for the Future, Washington, DC. November 20.

Keenan, R.E. 1989. Examination of potential risks from exposure to dioxin in sludge used to reclaim abandoned strip mines. Invited lecture to professional development course The Risk Assessment of Environmental and Human Health Hazards, 28th Annual Meeting of the Society of Toxicology, Atlanta, GA. February 27.

Keenan, R.E. 1989. Examining environmental and human health impacts. Invited lecture to Cornell University seminar What Happens When the Landfill Fills Up? Cornell University, Albany, NY. March 9.

Keenan, R.E. 1988. How clean is clean? The use of risk-driven remediation as an approach to solving our hazardous waste problems. Invited paper to the seminar series On-site Corrective Action Solutions for RCRA/CERCLA Sites, Houston, St. Louis and San Diego.

Keenan, R.E. 1986. Relevant issues in setting sludge utilization regulations. Invited lecture to 1986 NCASI Northeast Regional Meeting, Boston, MA. October 30.

Keenan, R.E. 1985. Comparative hazard and benefits assessment via ranking scales and computer graphics. Invited lecture to National Risk/Benefits Assessment Policy Work Symposium, Ottawa, Ontario. March 7.

Professional Meetings Organized and Chaired

Thirty-fourth Annual International Conference on Soils, Sediments, Water and Energy of the Association for Environmental Health and Sciences Foundation, Special Session on *New Challenges in Evaluating and Communicating Health Risks*, Amherst, MA. 2018.

Thirty-third Annual International Conference on Soils, Sediments, Water and Energy of the Association for Environmental Health and Sciences Foundation, Special Session on *Biomonitoring – Strategies and Uses for Risk Assessment and Stakeholder Communication*, Amherst, MA. 2017.

Thirty-second Annual International Conference on Soils, Sediments, Water and Energy of the Association for Environmental Health and Sciences Foundation, Special Session on *Use of Decision Analysis and Probabilistic Tools to Manage Environmental Risk*, Amherst, MA. 2016.

Thirty-first Annual International Conference on Soils, Sediments, Water and Energy of the Association for Environmental Health and Sciences Foundation, Special Session on

Perfluorinated Compounds of Emerging Concern—Challenges, Perspectives, and Risk Considerations, Amherst, MA. 2015.

Thirtieth Annual International Conference on Soils, Sediments, Water and Energy of the Association for Environmental Health and Sciences Foundation, Special Session on *Quantifying Human Exposures to Contaminants of Emerging Concern in Soils and Sediments*, Amherst, MA. 2014.

Twenty-Ninth Annual International Conference on Soils, Sediments, Water and Energy of the Association for Environmental Health and Sciences Foundation, Special Session on *Quantifying Human Exposures to Environmental Contaminants in Soils and Sediments*, Amherst, MA. 2013.

Twenty-Eighth Annual International Conference on Soils, Sediments, Water and Energy of the Association for Environmental Health and Sciences Foundation, Special Session on *Assessing and Managing Human Health Risks in the U.S.—Striking a Balance between Costs, Benefits, Efficacy, and Unintended Consequences*, Amherst, MA. 2012.

Thirty-Sixth Annual Meeting of the Society of Toxicology, Poster/Discussion Session on the Development and Applications of Probabilistic Reference Doses, Cincinnati, Ohio. 1997.

Fifteenth International Symposium on Chlorinated Dioxins and Related Compounds (Dioxin '95), Ecotoxicology Session. Edmonton, Alberta. 1995.

Society for Risk Analysis Annual Meeting, Workshop on Application of Monte Carlo Techniques to Exposure Assessment. Baltimore, MD. 1994.

Tenth International Symposium on Chlorinated Dioxins and Related Compounds (Dioxin '90), Risk Assessment Discussion Session. Bayreuth, West Germany. 1990.

Haztech International '90, Risk Assessment Sessions (2). Pittsburgh, PA. 1990.

Ninth International Symposium on Chlorinated Dioxins and Related Compounds (Dioxin '89), Pulp and Paper Symposium. Toronto, Ontario. 1989.

Fourth Annual Conference on Petroleum Contaminated Soils, Regulatory Session. Amherst, MA. 1989.

Understanding Toxicology and Chemical Risk Assessment—A National Symposium for Risk Managers and Corporate Counsel, Conference Organizer and Chairman, University of Massachusetts Division of Public Health. Portland, ME. 1984.

North American Conference on Pesticide Spray Drift and Chemical Trespass, Conference Organizer and Chairman, Maine Board of Pesticides Control. Portland, ME. 1984.

R.K. Mellon/Yale University on Chemical Control and Long-Term Management of Gypsy Moth, Conference Organizer and Chairman. New Haven, CT. 1983.

TESTIMONY

Keenan, R.E. 2019. A toxicological evaluation for establishing a reference dose (RfD) for use in site-specific risk assessment of sulfolane, a chemical substance without toxicity values on EPA's IRIS database. Expert testimony at trial in the Superior Court for the State of Alaska Fourth Judicial District Court, Fairbanks, Case No. 4FA-14-01544CI (*State of Alaska and City of North Pole v. Williams Alaska Petroleum Inc., The Williams Companies, Inc., Flint Hills Resources Alaska, LLC, and Flint Hills Resources, LLC*).

Keenan, R.E. 2016. An affirmative characterization of the Centredale Manor Restoration Project Superfund Site human health and ecological risk assessments. Expert testimony at trial in U.S. District Court, District of Rhode Island, Civil No. 11-023 (*Emhart Industries, Inc., et al. v. United States Department of the Air Force et al.*). October 3, 4.

Keenan, R.E. 2014. A characterization of potential risks to human health and an evaluation of ecological effects to aquatic biota due to mercury in the lower Penobscot River and Estuary. Expert testimony at trial in U.S. District Court, District of Maine, Civil No. 1:00-cv-00069-JAW (*Natural Resources Defense Council et al. v. HoltraChem Manufacturing LLC et al.)*. Bangor, ME. June 20, 23, 24.

Keenan, R.E. 2010. An assessment of attic dust samples collected in Dierks, Arkansas, using chemical forensic multivariate statistical methods. Expert testimony at trial before jury in U.S. District Court, Western District of Arkansas, Texarkana Division, Case No. 4:07cv4037 (*Rhonda Brasel, Individually and as Next Best Friend and Guardian of Christopher Albright and Nathan K. Thomas, et al. v. Weyerhaeuser Company, et al.*). Texarkana, AR. September 27.

Keenan, R.E. 2010. Human health implications related to corrective action alternatives at the former HoltraChem facility. Expert Testimony in Adjudicatory Hearing before the Maine Board of Environmental Protection on Appeal of Designation of Uncontrolled Hazardous Substance Site and Order Concerning Chlor-alkali Manufacturing Facility. Augusta, ME. February 2.

Keenan, R.E. 2002. An evaluation of potential human health risks to anglers and their families from ingesting fish containing methyl mercury from the Penobscot River. Expert testimony at trial in U.S. District Court, District of Maine, Docket No. 00-69-B (*Maine People's Alliance & Natural Resources Defense Council, Inc. v. HoltraChem Manufacturing Company, LLC and Mallinckrodt, Inc.*). Portland, ME. March.

Keenan, R.E. 2001. Dioxin TEQs overstate the carcinogenic potency of PCBs. Public hearing testimony to the Executive Committee of the EPA Science Advisory Board, Washington, DC. May 15.

Keenan, R.E. 1991. Testimony in public hearing before EPA TSCA Docket No. OPTS-62100: Proposed Rule for the Land Application of Sludge from Pulp and Paper Mills Using Chlorine and Chlorine Derivative Bleaching Processes (56 FR 21802), Washington, DC. October 29.

Keenan, R.E. 1991. Rebuttal testimony in adjudicatory hearing before the Environmental Quality Commission of the State of Oregon regarding NPDES Waste Discharge Permits 100715 and 100716. September 4.

Keenan, R.E. 1991. A hazard evaluation of the metal and dioxin concentrations in the sludge/ash, lime mud and leachate at the James River Old Town Mill. Testimony in public hearing before the Old Town Planning Board, Old Town, ME. April 2.

Keenan, R.E. 1991. Establishing a health-based water quality standard for dioxin in West Virginia. Testimony in public hearing before the West Virginia State Water Resources Board on Proposed Amendments and Revisions to State Water Resources Board, 46 CSR 1 Title 46 Legislative Rule Series 1 Requirements Governing Water Quality Standards. Charleston, WV. June 20.

Keenan, R.E. 1991. Expert testimony in public hearing concerning the petition for rule amendment to establish a health-based, water quality standard for 2,3,7,8,-TCDD. Environmental Quality Commission, Portland, OR. June 13.

Keenan, R.E. 1991. Establishing a health-based water quality standard for dioxin in Alabama. Testimony in public hearing before the Alabama Environmental Management Commission, Montgomery, AL. January 17.

Keenan, R.E. 1991. Establishing a health-based water quality standard for dioxin in Mississippi. Testimony in public hearing before the Mississippi Department of Environmental Quality, Starkville, MS. January 29.

Keenan, R.E. 1991. Establishing a health-based water quality standard for dioxin in Mississippi. Testimony in public hearing before the Mississippi Department of Environmental Quality, Jackson, MS. January 30.

Keenan, R.E. 1991. A toxicologic update concerning the carcinogenic dose response of dioxin. Testimony in public hearing before the Arkansas Commission of Pollution Control and Ecology regarding NPDES No. AR0001970 Waste Discharge Requirements for International Paper Company and NPDES No. AR0001210 Waste Discharge Requirements for Georgia-Pacific Corporation, Little Rock, AR. January 3.

Keenan, R.E. 1991. Establishing a health-based water quality standard for dioxin in Florida. Testimony in public hearing before the State of Florida Environmental Regulation Commission, Orlando, FL. June 5.

Keenan, R.E. 1990. Establishing a health-based water quality standard for dioxin in South Carolina. Testimony in public hearing before the South Carolina Water Quality Commission, Columbia, SC. August 1.

Keenan, R.E. 1990. Establishing a health-based water quality standard for dioxin in North Carolina. Testimony in public hearing before the North Carolina Environmental Management Commission - Water Quality Committee, Raleigh, NC. July 11.

Keenan, R.E. 1990. Determination of acceptable levels of human exposure to dioxin. Testimony in public hearing before the Florida Department of Environmental Regulation, Tallahassee, FL. May 1.

Keenan, R.E. 1990. Amendments to Georgia water use classifications and water quality standards. Testimony in public hearing before the Georgia Board of Natural Resources, Atlanta, GA. March 13.

Keenan, R.E. 1990. Establishing a health-based water quality standard for dioxin in Arkansas. Testimony in public hearing before the Arkansas Commission of Pollution Control and Ecology, Little Rock, AR. August 27.

Keenan, R.E. 1990. Establishing a health-based water quality standard for dioxin in South Carolina. Testimony in public hearing before the South Carolina Water Quality Commission, Georgetown, SC. August 2.

Keenan, R.E., E.R. Rand, M.S. Sauer, J.W. Knight, and J.M. Michaud. 1990. Examination of potential risks from exposure to dioxin in soils amended with sludge or ash. Testimony in public hearing before the New Hampshire Department of Environmental Services and the Towns of Milan and Berlin, Milan, NH. June 19.

Keenan, R.E. 1990. Evaluation of emissions from proposed sludge drying operation. Testimony in public hearing before the Wisconsin Department of Natural Resources, Texas, WI. May 23.

Keenan, R.E. 1990. L.D. 2394. - An act to clarify the process by which the Board of Environmental Protection regulates the discharge of toxic substances to the state's surface waters. Testimony in public hearing before the Maine Legislative Committee on Energy and Natural Resources, Augusta, ME. March 9.

Keenan, R.E. 1990. Proposed revisions to Minnesota Water Quality Standards. Testimony in public hearing before the Minnesota Pollution Control Agency, St. Paul, MN. March 2.

Keenan, R.E. 1990. Establishing a health-based water quality standard for dioxin in South Carolina. Testimony in public hearing before the South Carolina Water Quality Commission, Greenville, SC. July 31.

Keenan, R.E. 1989. Health and environmental risks associated with recycling sludge and residuals. Testimony in public hearing before the Maine Land Use Regulation Commission regarding Proposed Changes to Chapter 10 Land Use Districts and Standards, Bangor, ME. April 20.

Keenan, R.E. 1989. Testimony presented at public hearing before the California Regional Water Quality Control Board regarding NPDES No. CA0004065 Waste Discharge Requirements for Simpson Paper Company, Shasta Mill, Redding, CA.

Keenan, R.E. 1989. Testimony presented at public hearing before the Maine Legislative Joint Committee on Energy and Natural Resources regarding LD1162 -- An Act Regarding Sludge Spreading, Augusta, ME. April 24.

Cavaney, R., R. Estridge, and R.E. Keenan. 1988. Testimony on behalf of the American Paper Institute before the Subcommittee on Health and the Environment of the Committee on Energy and Commerce, U.S. House of Representatives, Washington, DC. December 8.

Keenan, R.E. 1988. Assessment of potential risks to consumers and to pulp and paper mill workers from dermal exposure to dioxin in bleached pulp, paper and pulp-based products. Testimony on behalf of the American Paper Institute before the U.S. Congress Office of Technology Assessment, Washington, DC. November 15.

Keenan, R.E., and B.W. Found. 1988. Assessment of potential risks to humans and to wildlife from herbicide applications on powerline rights-of-way. Testimony in public hearing before the Towns of Dixfield (November 7) and Pownal (February 24), ME.

Keenan, R.E. 1987. Assessment of potential health risks from dermal exposure to dioxin in paper products. Testimony presented on behalf of the American Paper Institute to the U.S. Environmental Protection Agency, the Food and Drug Administration, and the Consumer Products Safety Council, Washington, DC. October 15.

Keenan, R.E. 1987. Potential impacts on human health and wildlife species from forestland application of paper mill sludge. Testimony in public hearing before the Town of Standish regarding S.D. Warren application to apply sludge and residuals under Chapter 567, Steep Falls, ME. September 12.

Keenan, R.E. 1986. Potential impacts on wildlife from dioxin-containing sludges. Testimony in public hearing before Maine Board of Environmental Protection regarding Proposed Amendment to Chapter 567 Dioxin Standards, Rules for Land Application of Sludge and Residuals, Augusta, ME. April 16.

Lawrence, F.H., and R.E. Keenan. 1986. Assessment of human health risks and potential impacts on terrestrial wildlife from exposure to dioxin in BYPRO paper mill sludge used to reclaim abandoned strip mine sites. Testimony in public hearing before the Ohio Environmental Protection Agency, Logan, OH. September 25.

APPENDIX B

DATA SOURCES AND SUMMARIES FOR SPOKANE RIVER SURFACE WATER, SEDIMENT, AND GAMEFISH

PREFACE

This appendix provides the data sources and total polychlorinated biphenyls (PCBs) concentrations in surface water, sediments, and fish tissue that I relied upon for my expert report.

Surface water, sediments, and gamefish have been collected from the Spokane River for a number of years. To have an appropriate representation of the hypothetical current risks from concurrent exposures to all of these media, only those samples collected from similar periods were used for my analysis. I used the surface water sample collection years, which were in 2003 and from 2012 through 2017, to guide the selection of sediment and gamefish samples for my assessment. Therefore, I relied on sediment samples that were collected from 2003, 2004, and 2013, and gamefish samples that were collected from 2001, 2003, 2004, 2005, and 2012 for my analysis. Gamefish collected in 2001 were included in my analysis because they represented a large data set of samples collected from Long Lake.

Total PCBs were calculated as the sum of the reported Aroclor PCBs ($TotPCB_{ar}$) or as the sum of reported PCB congeners ($TotPCB_{cong}$). Analytical results that were rejected by the original data sources were excluded from the total PCBs calculations.[1] A minimum analysis of 150 PCB congeners was used as a threshold for calculating $TotPCB_{cong}$. I selected this value because it corresponds to the minimum number of PCB congeners or coeluting PCB congener groups that are typically evaluated using high resolution gas chromatography/mass spectrometry methods, such as EPA Method 1668 (USEPA 2010[2]). When data sources reported both Aroclor PCB and PCB congener data for the same samples, I used the larger of the two results as the total PCBs concentration for those samples.

In cases where samples were collected as field duplicates, I combined the results from the sample-duplicate pairs using the following decision rules before summarizing and evaluating the results:

- If PCBs were detected in both the sample and duplicate, the average of the sample-duplicate pair was used as the combined sample results.
- If PCBs were detected in either the sample or duplicate but not both, then the detected result was used as the combined sample result.

[1] This rarely occurred across the data sets. An exception was the Aroclor PCB analyses for the surface water samples collected under Study ID SGOL001, where all but one of the sample results were rejected.
[2] USEPA. 2010. Method 1668C: Chlorinated biphenyl congeners in water, soil, sediment, biosolids, and tissue by HRGC/HRMS. EPA-820-R-10-005. U.S. Environmental Protection Agency, Office of Water, Office of Science and Technology. April.

- If PCBs were not detected in either the sample or duplicate, then the combined sample result was treated as a non-detect at the larger of the two non-detect results.

The subareas of the Spokane River and features (e.g., dams) and river miles that define them are shown in Table B-1. The dam reaches in the Spokane River correspond to those shown on the Washington State Department of Health (WDOH 2009[3]) fish consumption advisory map, with the following additions:

- The Upper Falls Dam and Monroe Street Dam within the City of Spokane are located within the Upriver Dam to Nine Mile Dam reach.
- Only one sediment sample was collected between Long Lake Dam and Little Falls Dam, located at River Mile 29,[4] so a separate subarea bounded downstream by Little Falls Dam was not developed.

The Washington State portion of the Spokane River consists of the Middle and Lower Spokane watersheds, which correspond to the Washington State Department of Ecology (Ecology) Water Resource Inventory Area (WRIAs) 57 and 54, respectively. Lake Roosevelt is contained within three Ecology WRIA watersheds (Upper, Middle, and Lower). Only the gamefish samples collected from within Lower Lake Roosevelt (WRIA 53) and the southern portion of Middle Lake Roosevelt (WRIA 58) were included in this assessment. The evaluated boundaries within Lake Roosevelt extend from the Grand Coulee Dam north (upstream) to Barnaby Island.[5] These bound the location where the Spokane River discharges to the Lake Roosevelt.

I evaluated the media-specific total PCBs results in the following ways:

- **Surface Water**: The Spokane River surface water results were summarized on a river-wide basis (the portion of the Spokane River from the Idaho-Washington border to the junction with Lake Roosevelt) and also by river reach (Tables B-2a-c).

  The surface water sample collection methods varied across the source data sets. For example, Ecology Study ID WHOB003 ("Assessment of Methods for Sampling Low-Level Toxics in Surface Waters") reported results for samples collected by hand grab and submersible electric pumps. The data were used regardless of the collection methods.
- **Surface Sediments**: The Spokane River sediment results were summarized on a river-wide basis and by the four river reaches (Tables B-3a-c).
- **Gamefish**: The Spokane River gamefish results were summarized on a river-wide plus Lake Roosevelt basis, as well as by the four dam reaches and Lake Roosevelt

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[3] WDOH. 2009. Spokane River Safe Fishing Guide. DOH 334-123. Available at: https://www.doh.wa.gov/Portals/1/Documents/Pubs/334-123.pdf. Washington State Department of Health.
[4] https://www.nwcouncil.org/reports/columbia-river-history/spokaneriver
[5] The GIS latitude and longitude coordinates are 47.956 and -118.981 for the Grand Coulee Dam and 48.437 and -118.216 for Barnaby Island.

(Tables B-4a-d). As stated earlier, the Lake Roosevelt samples I included in my analyses were collected from Lower Lake Roosevelt and the southern portion of Middle Lake Roosevelt.

The sampling locations for surface water, surface sediments, and gamefish are shown in Figures B-1, B-2, and B-3, respectively.

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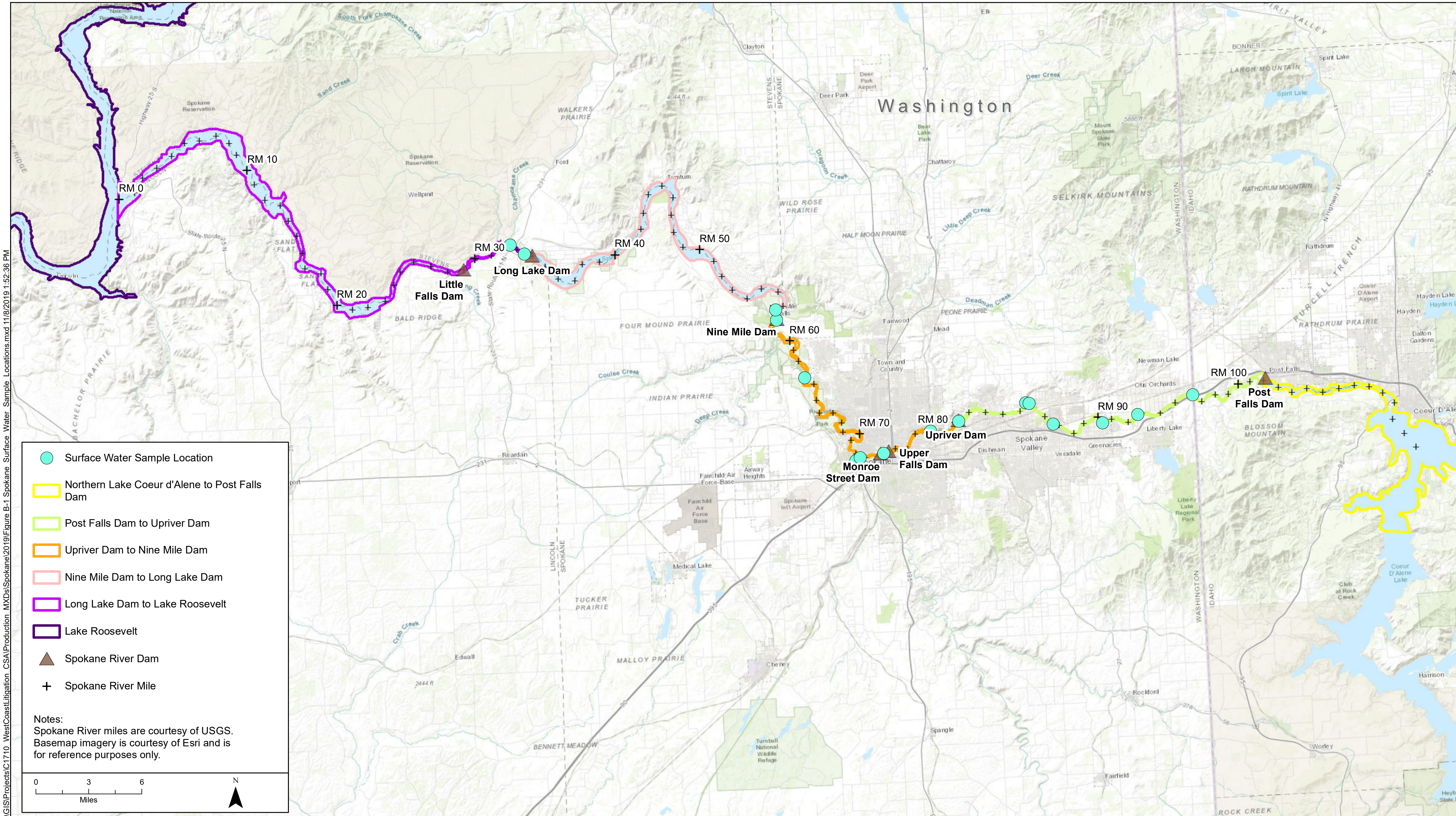

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Figure B-1.
Surface Water Sampling Locations for PCBs in the Spokane River

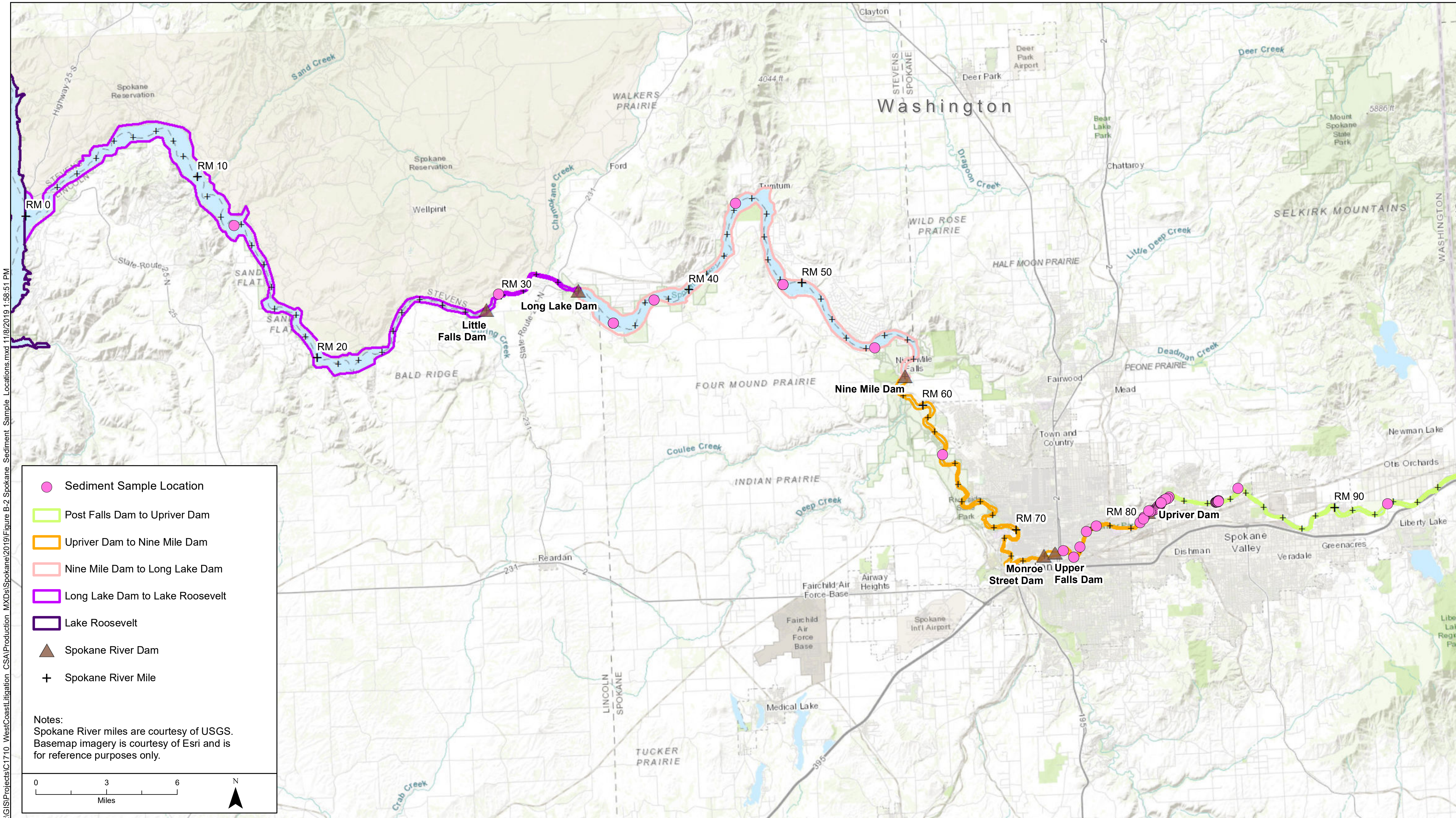

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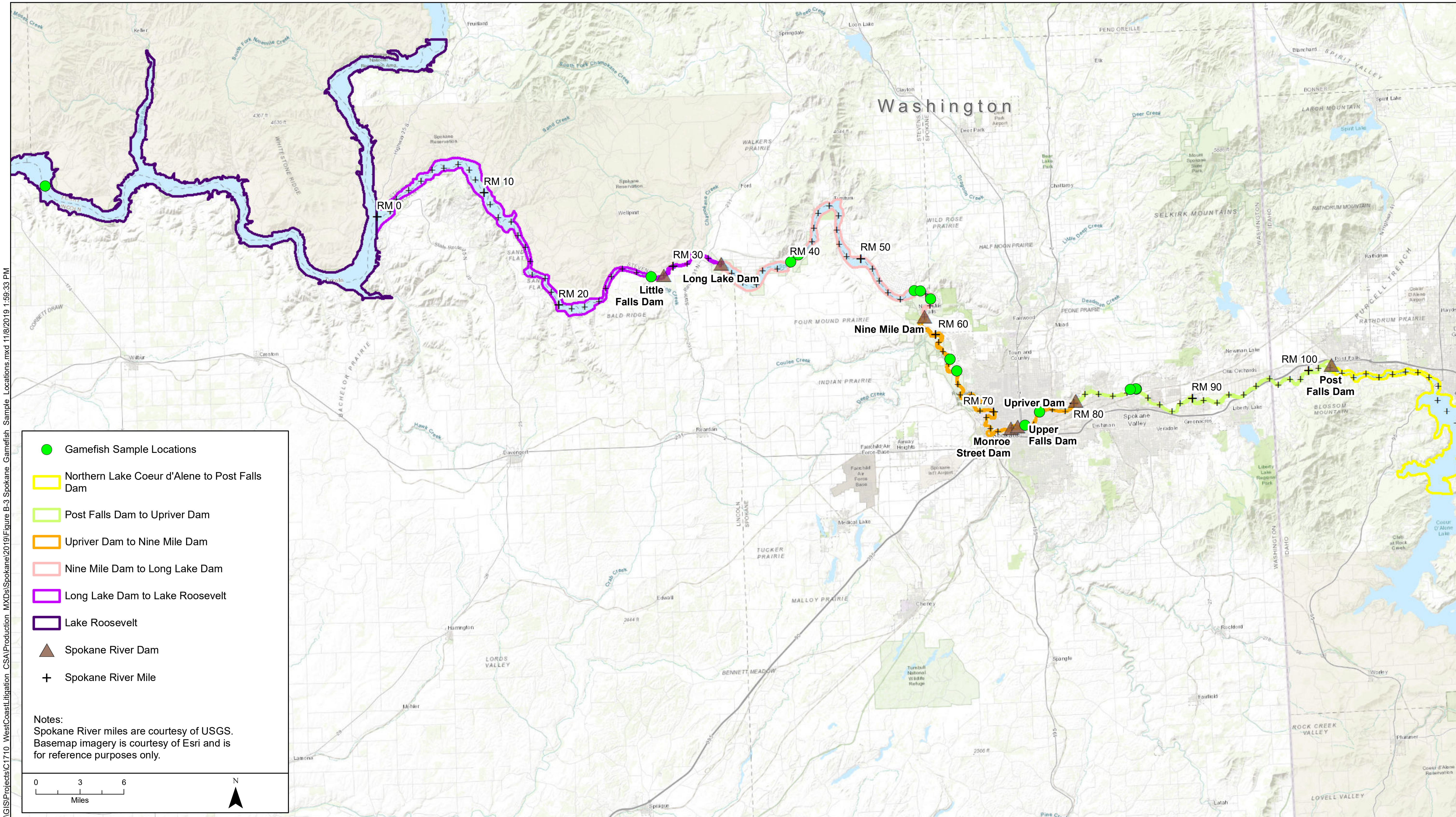
Figure B-2.
Surface Sediment Sampling Locations for PCBs in the Spokane River



integral consulting inc.

Figure B-3.
Gamefish Sampling Locations for PCBs in the Spokane River and Lake Roosevelt

Tables

Table B-1. Spokane River and Lake Roosevelt Subarea Designations for Evaluated Surface Water, Sediments, and Gamefish Samples

			PCB Data Available		
Watersheds	Subareas or Dam Reaches	Spokane River Mile Ranges	Surface Water	Surface Sediment	Gamefish
Middle Spokane River	Idaho boundary (near Post Falls Dam) to Upriver Dam	RM 74.2 to 102	◆	◆	◆
Middle Spokane River	Upriver Dam to Nine Mile Dam	RM 58 to RM 74.2	◆	◆	◆
Lower Spokane River	Nine Mile Dam to Long Lake Dam (Long Lake)	RM 34 to RM 58	◆	◆	◆
Lower Spokane River	Long Lake Dam to Lake Roosevelt Juncture[(a)]	RM 0 to RM 34	◆	◆	◆
Lake Roosevelt (see note)	Lower Lake Roosevelt and southern portion of Middle Lake Roosevelt	NA		(b)	◆

Notes:

The Upper Falls Dam and Monroe Street Dam within the City of Spokane are located within the Upriver Dam to Nine Mile Dam subarea.

Little Falls Dam is located at RM 29 (https://www.nwcouncil.org/reports/columbia-river-history/spokaneriver) but there was only one sediment sample collected between Long Lake Dam and Little Falls Dam so a separate subarea bounded by Little Falls Dam was not developed.

Lake Roosevelt includes three Ecology WRIA watersheds (Upper, Middle and Lower). Only those samples collected from Lower Lake Roosevelt (WRIA 53) and the southern portion of Middle Lake Roosevelt (WRIA 58) were included in this assessment. These reaches bound the location where the Spokane River discharges to the lake.

Ecology = Washington State Department of Ecology

NA = not applicable

PCB = polychlorinated biphenyl

RM = river mile

WRIA = Water Resource Inventory Area

[a] The Long Lake Dam to Lake Roosevelt juncture reach is also identified as the "Spokane Arm of Lake Roosevelt."

[b] The sediment samples from Lake Roosevelt with available PCB data were far from the juncture with the Spokane River (e.g., near the Grand Coulee Dam) and were excluded from this analysis.

Table B-2a. Summary of Ecology Studies, Collection Years, and Analytical Methods for Surface Water PCBs

EIM Study ID	Description	Analytical Method	Aroclor PCBs	PCB Congeners	Collection Years	Comment
BERA0009	Spokane River Toxics Preliminary Monitoring 2012 through 2013 - In Support of the Long-term Toxics Monitoring Strategy	EPA 1668C		◆	2012, 2013	Reported results for 182 to 187 PCB congeners or congener groups.
BERA0012	Spokane River PCBs and Other Toxics: Long-Term Monitoring at the Spokane Tribal Boundary	EPA 1668C		◆	2016	Reported results for 159 PCB congeners or congener groups.
DSER0010	Spokane River PCB Source Assessment 2003-2007 (formerly Spokane River PCB TMDL)	EPA 1668A		◆	2003	Reported results for 163 PCB congeners or congener groups.
EA0318	Riverfront Park Spokane	EPA 608	◆		2016	Analyzed for 9 Aroclor PCBs.
SRRTTF-2014	Spokane River Regional Toxics Task Force 2014 Synoptic Dry Weather Survey and Confidence Testing for PCBs in Surface Water	EPA 1668C		◆	2014	Reported results for 159 PCB congeners or congener groups.
SRRTTF-2015	Spokane River Regional Toxics Task Force 2015 Synoptic Dry Weather Survey	EPA 1668C		◆	2015	Reported results for 159 PCB congeners or congener groups.
SRRTTF-2016	Spokane River Regional Toxics Task Force 2016 Monthly Monitoring	EPA 1668C		◆	2016	Reported results for 159 PCB congeners or congener groups.
WHOB003	Assessment of Methods for Sampling Low-Level Toxics in Surface Waters	EPA 1668C		◆	2017	Reported results for 159 PCB congeners or congener groups.

Notes:

Descriptions from Ecology EIM database (https://ecology.wa.gov/Research-Data/Data-resources/Environmental-Information-Management-database).

The results for the single sample collected in the Spokane River in EIM Study ID "EA0318" was also reported in EIM Study ID "VCEA0318".

Ecology = Washington State Department of Ecology

EIM = Environmental Information Management System

EPA = U.S. Environmental Protection Agency

PCB = polychlorinated biphenyl

TMDL = total maximum daily load

Table B-2b. Concentrations of Total PCBs in Surface Water Samples Collected from the Spokane River

Study ID	Sample ID	Location ID	Reach	Date Collected	Year Collected	Sample Type	Parent Sample	Conc	Units	Flag	Detected	Aroclor or Congener Count	Total PCB Type	Location Latitude	Location Longitude	Comment
BERA0009	1210040-01	Stateline	Post Falls Dam to Upriver Dam	10/24/2012	2012	S		0.0000409	ppb	U	No	187	TotPCBcong	47.6977	-117.0424	[1]
BERA0009	1210040-02	UPRIVER DAM SW	Post Falls Dam to Upriver Dam	10/24/2012	2012	S		0.0000246	ppb		Yes	187	TotPCBcong	47.6850	-117.3283	
BERA0009	1210040-03	57A123	Upriver Dam to Nine Mile Dam	10/24/2012	2012	S		0.0000169	ppb		Yes	187	TotPCBcong	47.6564	-117.4552	
BERA0009	1210040-04	SPMDTR-SPOK	Upriver Dam to Nine Mile Dam	10/24/2012	2012	S		0.0000234	ppb		Yes	187	TotPCBcong	47.7747	-117.5444	
BERA0009	1210040-05	Chamokane	Long Lake Dam to Lake Roosevelt	10/24/2012	2012	S		0.0000142	ppb		Yes	187	TotPCBcong	47.8375	-117.8483	
BERA0009	1305006-01	Stateline	Post Falls Dam to Upriver Dam	5/23/2013	2013	S		0.000112	ppb		Yes	182	TotPCBcong	47.6977	-117.0424	
BERA0009	1305006-02	UPRIVER DAM SW	Post Falls Dam to Upriver Dam	5/23/2013	2013	S		0.0000676	ppb		Yes	182	TotPCBcong	47.6850	-117.3283	
BERA0009	1305006-03	57A123	Upriver Dam to Nine Mile Dam	5/23/2013	2013	S		0.000193	ppb		Yes	182	TotPCBcong	47.6564	-117.4552	
BERA0009	1305006-04	SPMDTR-SPOK	Upriver Dam to Nine Mile Dam	5/23/2013	2013	S		0.000106	ppb		Yes	182	TotPCBcong	47.7747	-117.5444	
BERA0009	1305006-05	Chamokane	Long Lake Dam to Lake Roosevelt	5/23/2013	2013	S		0.000048	ppb		Yes	182	TotPCBcong	47.8375	-117.8483	
BERA0012	1602016-13	UGM	Long Lake Dam to Lake Roosevelt	1/26/2016	2016	S		0.0000294	ppb		Yes	159	TotPCBcong	47.8451	-117.8651	
BERA0012	1602016-14	UGM	Long Lake Dam to Lake Roosevelt	1/26/2016	2016	FD	1602016-13	0.0000303	ppb		Yes	159	TotPCBcong	47.8451	-117.8651	
DSER0010	3438100	HARVARD	Post Falls Dam to Upriver Dam	10/20/2003	2003	S		0.000556	ppb	U	No	150	TotPCBcong	47.6837	-117.1104	[1]
DSER0010	3448100	PLANTEFRY	Post Falls Dam to Upriver Dam	10/28/2003	2003	S		0.000545	ppb	U	No	163	TotPCBcong	47.6976	-117.2456	[1]
DSER0010	3454105	NINEM SPM	Upriver Dam to Nine Mile Dam	11/3/2003	2003	S		0.00013	ppb		Yes	163	TotPCBcong	47.7264	-117.5131	
EA0318	HSBDW-1123:	HSBDW	Post Falls Dam to Upriver Dam	11/23/2016	2016	S		0.021	ppb	U	No	9	TotPCBar	47.6615	-117.4213	[2]
SRRTTF-2014	L21456-5	SRRTTF_SR8a	Post Falls Dam to Upriver Dam	5/13/2014	2014	(FD)	NA	0.0000457	ppb		Yes	159	TotPCBcong	47.6792	-117.2137	[3]
SRRTTF-2014	L21466-11	SRRTTF_SR8a	Post Falls Dam to Upriver Dam	5/17/2014	2014	S		0.0000646	ppb		Yes	159	TotPCBcong	47.6792	-117.2137	
SRRTTF-2014	L21466-12	SRRTTF_SR8a	Post Falls Dam to Upriver Dam	5/17/2014	2014	FD	L21466-11	0.0000863	ppb		Yes	159	TotPCBcong	47.6792	-117.2137	
SRRTTF-2014	L21466-15	SRRTTF_SR8a	Post Falls Dam to Upriver Dam	5/19/2014	2014	S		0.0000701	ppb		Yes	159	TotPCBcong	47.6792	-117.2137	
SRRTTF-2014	L21466-16	SRRTTF_SR8a	Post Falls Dam to Upriver Dam	5/19/2014	2014	FD	L21466-15	0.0000752	ppb		Yes	159	TotPCBcong	47.6792	-117.2137	
SRRTTF-2014	L21466-4	SRRTTF_SR8a	Post Falls Dam to Upriver Dam	5/15/2014	2014	S		0.0000742	ppb		Yes	159	TotPCBcong	47.6792	-117.2137	

Table B-2b. Concentrations of Total PCBs in Surface Water Samples Collected from the Spokane River

Study ID	Sample ID	Location ID	Reach	Date Collected	Year Collected	Sample Type	Parent Sample	Conc	Units	Flag	Detected	Aroclor or Congener Count	Total PCB Type	Location Latitude	Location Longitude	Comment
SRRTTF-2014	L21466-5	SRRTTF_SR8a	Post Falls Dam to Upriver Dam	5/15/2014	2014	FD	L21466-4	0.000119	ppb		Yes	159	TotPCBcong	47.6792	-117.2137	
SRRTTF-2014	L21476-5	SRRTTF_SR8a	Post Falls Dam to Upriver Dam	5/13/2014	2014	S		0.000109	ppb		Yes	159	TotPCBcong	47.6792	-117.2137	
SRRTTF-2014	L21531-1	SRRTTF_SR8a	Post Falls Dam to Upriver Dam	5/13/2014	2014	S		0.0000632	ppb		Yes	159	TotPCBcong	47.6792	-117.2137	
SRRTTF-2014	L21476-1	SRRTTF_SR8a	Post Falls Dam to Upriver Dam	5/21/2014	2014	S		0.0000616	ppb		Yes	159	TotPCBcong	47.6792	-117.2137	
SRRTTF-2014	L21531-2	SRRTTF_SR8a	Post Falls Dam to Upriver Dam	5/21/2014	2014	FD	L21476-1	0.0000671	ppb		Yes	159	TotPCBcong	47.6792	-117.2137	
SRRTTF-2014	L21874-10	SRRTTF_SR7	Post Falls Dam to Upriver Dam	8/12/2014	2014	S		0.00019	ppb		Yes	159	TotPCBcong	47.6971	-117.2418	
SRRTTF-2014	L21874-14	SRRTTF_SR1	Nine Mile Dam to Long Lake Dam	8/12/2014	2014	S		0.000184	ppb		Yes	159	TotPCBcong	47.7830	-117.5448	
SRRTTF-2014	L21874-16	SRRTTF_SR1	Nine Mile Dam to Long Lake Dam	8/12/2014	2014	FD	L21874-14	0.00022	ppb		Yes	159	TotPCBcong	47.7830	-117.5448	
SRRTTF-2014	L21874-17	SRRTTF_SR3	Upriver Dam to Nine Mile Dam	8/12/2014	2014	S		0.000181	ppb		Yes	159	TotPCBcong	47.6589	-117.4497	
SRRTTF-2014	L21874-22	SRRTTF_SR9	Post Falls Dam to Upriver Dam	8/14/2014	2014	S		0.00007	ppb		Yes	159	TotPCBcong	47.6784	-117.1534	
SRRTTF-2014	L21874-8	SRRTTF_SR4	Upriver Dam to Nine Mile Dam	8/13/2014	2014	S		0.000195	ppb		Yes	159	TotPCBcong	47.6781	-117.3628	
SRRTTF-2014	L21874-9	SRRTTF_SR9	Post Falls Dam to Upriver Dam	8/12/2014	2014	S		0.0000536	ppb		Yes	159	TotPCBcong	47.6784	-117.1534	
SRRTTF-2014	L21877-81	SRRTTF_SR1	Nine Mile Dam to Long Lake Dam	8/12/2014	2014	S		0.000165	ppb		Yes	159	TotPCBcong	47.7830	-117.5448	
SRRTTF-2014	L21877-87	SRRTTF_SR3	Upriver Dam to Nine Mile Dam	8/12/2014	2014	S		0.000155	ppb		Yes	159	TotPCBcong	47.6589	-117.4497	
SRRTTF-2014	L21877-88	SRRTTF_SR4	Upriver Dam to Nine Mile Dam	8/13/2014	2014	S		0.000148	ppb		Yes	159	TotPCBcong	47.6781	-117.3628	
SRRTTF-2014	L21877-91 i	SRRTTF_SR7	Post Falls Dam to Upriver Dam	8/12/2014	2014	S		0.000133	ppb		Yes	159	TotPCBcong	47.6971	-117.2418	
SRRTTF-2014	L21877-93 i	SRRTTF_SR9	Post Falls Dam to Upriver Dam	8/12/2014	2014	S		0.0000688	ppb		Yes	159	TotPCBcong	47.6784	-117.1534	
SRRTTF-2014	L21902-12	SRRTTF_SR4	Upriver Dam to Nine Mile Dam	8/14/2014	2014	S		0.00023	ppb		Yes	159	TotPCBcong	47.6781	-117.3628	
SRRTTF-2014	L21902-13	SRRTTF_SR7	Post Falls Dam to Upriver Dam	8/14/2014	2014	S		0.000151	ppb		Yes	159	TotPCBcong	47.6971	-117.2418	
SRRTTF-2014	L21902-14	SRRTTF_SR7	Post Falls Dam to Upriver Dam	8/16/2014	2014	S		0.00019	ppb		Yes	159	TotPCBcong	47.6971	-117.2418	
SRRTTF-2014	L21902-15	SRRTTF_SR4	Upriver Dam to Nine Mile Dam	8/16/2014	2014	S		0.000157	ppb		Yes	159	TotPCBcong	47.6781	-117.3628	
SRRTTF-2014	L21902-16	SRRTTF_SR1	Nine Mile Dam to Long Lake Dam	8/16/2014	2014	S		0.000218	ppb		Yes	159	TotPCBcong	47.7830	-117.5448	

Table B-2b. Concentrations of Total PCBs in Surface Water Samples Collected from the Spokane River

Study ID	Sample ID	Location ID	Reach	Date Collected	Year Collected	Sample Type	Parent Sample	Conc	Units	Flag	Detected	Aroclor or Congener Count	Total PCB Type	Location Latitude	Location Longitude	Comment
SRRTTF-2014	L21902-11	SRRTTF_SR3	Upriver Dam to Nine Mile Dam	8/14/2014	2014	S		0.000197	ppb		Yes	159	TotPCBcong	47.6589	-117.4497	
SRRTTF-2014	L21902-19	SRRTTF_SR3	Upriver Dam to Nine Mile Dam	8/14/2014	2014	FD	L21902-11	0.000162	ppb		Yes	159	TotPCBcong	47.6589	-117.4497	
SRRTTF-2014	L21902-20	SRRTTF_SR3	Upriver Dam to Nine Mile Dam	8/16/2014	2014	S		0.000327	ppb		Yes	159	TotPCBcong	47.6589	-117.4497	
SRRTTF-2014	L21902-23	SRRTTF_SR9	Post Falls Dam to Upriver Dam	8/16/2014	2014	S		0.000049	ppb		Yes	159	TotPCBcong	47.6784	-117.1534	
SRRTTF-2014	L21902-8	SRRTTF_SR4	Upriver Dam to Nine Mile Dam	8/18/2014	2014	S		0.000169	ppb		Yes	159	TotPCBcong	47.6781	-117.3628	
SRRTTF-2014	L21902-24	SRRTTF_SR4	Upriver Dam to Nine Mile Dam	8/18/2014	2014	FD	L21902-8	0.000136	ppb		Yes	159	TotPCBcong	47.6781	-117.3628	
SRRTTF-2014	L21902-6	SRRTTF_SR9	Post Falls Dam to Upriver Dam	8/18/2014	2014	S		0.0000947	ppb		Yes	159	TotPCBcong	47.6784	-117.1534	
SRRTTF-2014	L21902-7	SRRTTF_SR7	Post Falls Dam to Upriver Dam	8/18/2014	2014	S		0.000434	ppb		Yes	159	TotPCBcong	47.6971	-117.2418	
SRRTTF-2014	L21902-9	SRRTTF_SR1	Nine Mile Dam to Long Lake Dam	8/14/2014	2014	S		0.00021	ppb		Yes	159	TotPCBcong	47.7830	-117.5448	
SRRTTF-2014	L21910-15	SRRTTF_SR9	Post Falls Dam to Upriver Dam	8/20/2014	2014	S		0.0000552	ppb		Yes	159	TotPCBcong	47.6784	-117.1534	
SRRTTF-2014	L21910-16	SRRTTF_SR7	Post Falls Dam to Upriver Dam	8/20/2014	2014	S		0.000181	ppb		Yes	159	TotPCBcong	47.6971	-117.2418	
SRRTTF-2014	L21910-17	SRRTTF_SR7	Post Falls Dam to Upriver Dam	8/20/2014	2014	FD	L21910-16	0.000194	ppb		Yes	159	TotPCBcong	47.6971	-117.2418	
SRRTTF-2014	L21910-18	SRRTTF_SR4	Upriver Dam to Nine Mile Dam	8/20/2014	2014	S		0.000216	ppb		Yes	159	TotPCBcong	47.6781	-117.3628	
SRRTTF-2014	L21910-3	SRRTTF_SR1	Nine Mile Dam to Long Lake Dam	8/18/2014	2014	S		0.000193	ppb		Yes	159	TotPCBcong	47.7830	-117.5448	
SRRTTF-2014	L21910-5	SRRTTF_SR3	Upriver Dam to Nine Mile Dam	8/18/2014	2014	S		0.000219	ppb		Yes	159	TotPCBcong	47.6589	-117.4497	
SRRTTF-2014	L21917-7	SRRTTF_SR1	Nine Mile Dam to Long Lake Dam	8/20/2014	2014	S		0.000245	ppb		Yes	159	TotPCBcong	47.7830	-117.5448	
SRRTTF-2014	L21917-9	SRRTTF_SR3	Upriver Dam to Nine Mile Dam	8/20/2014	2014	S		0.000194	ppb		Yes	159	TotPCBcong	47.6589	-117.4497	
SRRTTF-2014	L21932-10	SRRTTF_SR1	Nine Mile Dam to Long Lake Dam	8/24/2014	2014	S		0.000174	ppb		Yes	159	TotPCBcong	47.7830	-117.5448	
SRRTTF-2014	L21932-11	SRRTTF_SR1	Nine Mile Dam to Long Lake Dam	8/22/2014	2014	S		0.00018	ppb		Yes	159	TotPCBcong	47.7830	-117.5448	
SRRTTF-2014	L21932-13	SRRTTF_SR3	Upriver Dam to Nine Mile Dam	8/22/2014	2014	S		0.000418	ppb		Yes	159	TotPCBcong	47.6589	-117.4497	
SRRTTF-2014	L21932-16	SRRTTF_SR9	Post Falls Dam to Upriver Dam	8/24/2014	2014	S		0.0000494	ppb		Yes	159	TotPCBcong	47.6784	-117.1534	
SRRTTF-2014	L21932-17	SRRTTF_SR7	Post Falls Dam to Upriver Dam	8/24/2014	2014	S		0.000155	ppb		Yes	159	TotPCBcong	47.6971	-117.2418	

Table B-2b. Concentrations of Total PCBs in Surface Water Samples Collected from the Spokane River

Study ID	Sample ID	Location ID	Reach	Date Collected	Year Collected	Sample Type	Parent Sample	Conc	Units	Flag	Detected	Aroclor or Congener Count	Total PCB Type	Location Latitude	Location Longitude	Comment
SRRTTF-2014	L21932-18	SRRTTF_SR4	Upriver Dam to Nine Mile Dam	8/24/2014	2014	S		0.000134	ppb		Yes	159	TotPCBcong	47.6781	-117.3628	
SRRTTF-2014	L21932-5	SRRTTF_SR9	Post Falls Dam to Upriver Dam	8/22/2014	2014	S		0.0000388	ppb		Yes	159	TotPCBcong	47.6784	-117.1534	
SRRTTF-2014	L21932-6	SRRTTF_SR9	Post Falls Dam to Upriver Dam	8/22/2014	2014	FD	L21932-5	0.0000842	ppb		Yes	159	TotPCBcong	47.6784	-117.1534	
SRRTTF-2014	L21932-7	SRRTTF_SR7	Post Falls Dam to Upriver Dam	8/22/2014	2014	S		0.000144	ppb		Yes	159	TotPCBcong	47.6971	-117.2418	
SRRTTF-2014	L21932-8	SRRTTF_SR4	Upriver Dam to Nine Mile Dam	8/22/2014	2014	S		0.000152	ppb		Yes	159	TotPCBcong	47.6781	-117.3628	
SRRTTF-2014	L21932-9	SRRTTF_SR3	Upriver Dam to Nine Mile Dam	8/24/2014	2014	S		0.000176	ppb		Yes	159	TotPCBcong	47.6589	-117.4497	
SRRTTF-2015	L23783-17	SRRTTF_SR7	Post Falls Dam to Upriver Dam	8/19/2015	2015	S		0.000208	ppb		Yes	159	TotPCBcong	47.6971	-117.2418	
SRRTTF-2015	L23783-20	SRRTTF_SR7	Post Falls Dam to Upriver Dam	8/19/2015	2015	FD	L23783-17	0.000182	ppb		Yes	159	TotPCBcong	47.6971	-117.2418	
SRRTTF-2015	L23783-18	SRRTTF_SR8a	Post Falls Dam to Upriver Dam	8/19/2015	2015	S		0.000104	ppb		Yes	159	TotPCBcong	47.6792	-117.2137	
SRRTTF-2015	L23783-19	SRRTTF_SR9	Post Falls Dam to Upriver Dam	8/19/2015	2015	S		0.00008	ppb		Yes	159	TotPCBcong	47.6784	-117.1534	
SRRTTF-2015	L23783-21	SRRTTF_SR9	Post Falls Dam to Upriver Dam	8/20/2015	2015	S		0.0001	ppb		Yes	159	TotPCBcong	47.6784	-117.1534	
SRRTTF-2015	L23783-22	SRRTTF_SR8a	Post Falls Dam to Upriver Dam	8/20/2015	2015	S		0.0000756	ppb		Yes	159	TotPCBcong	47.6792	-117.2137	
SRRTTF-2015	L23783-25	SRRTTF_SR7	Post Falls Dam to Upriver Dam	8/20/2015	2015	S		0.000161	ppb		Yes	159	TotPCBcong	47.6971	-117.2418	
SRRTTF-2015	L23783-28	SRRTTF_SR4	Upriver Dam to Nine Mile Dam	8/20/2015	2015	S		0.000179	ppb		Yes	159	TotPCBcong	47.6781	-117.3628	
SRRTTF-2015	L23783-29	SRRTTF_SR3	Upriver Dam to Nine Mile Dam	8/20/2015	2015	S		0.000234	ppb		Yes	159	TotPCBcong	47.6589	-117.4497	
SRRTTF-2015	L23783-30	SRRTTF_SR3	Upriver Dam to Nine Mile Dam	8/21/2015	2015	S		0.000223	ppb		Yes	159	TotPCBcong	47.6589	-117.4497	
SRRTTF-2015	L23783-31	SRRTTF_SR4	Upriver Dam to Nine Mile Dam	8/21/2015	2015	S		0.000216	ppb		Yes	159	TotPCBcong	47.6781	-117.3628	
SRRTTF-2015	L23783-32	SRRTTF_SR7	Post Falls Dam to Upriver Dam	8/21/2015	2015	S		0.000185	ppb		Yes	159	TotPCBcong	47.6971	-117.2418	
SRRTTF-2015	L23783-33	SRRTTF_SR8a	Post Falls Dam to Upriver Dam	8/21/2015	2015	S		0.0000984	ppb		Yes	159	TotPCBcong	47.6792	-117.2137	
SRRTTF-2015	L23783-35	SRRTTF_SR8a	Post Falls Dam to Upriver Dam	8/21/2015	2015	FD	L23783-33	0.0000708	ppb		Yes	159	TotPCBcong	47.6792	-117.2137	
SRRTTF-2015	L23783-34	SRRTTF_SR9	Post Falls Dam to Upriver Dam	8/21/2015	2015	S		0.000181	ppb		Yes	159	TotPCBcong	47.6784	-117.1534	
SRRTTF-2015	L23783-36	SRRTTF_SR9	Post Falls Dam to Upriver Dam	8/22/2015	2015	S		0.000122	ppb		Yes	159	TotPCBcong	47.6784	-117.1534	

Table B-2b. Concentrations of Total PCBs in Surface Water Samples Collected from the Spokane River

Study ID	Sample ID	Location ID	Reach	Date Collected	Year Collected	Sample Type	Parent Sample	Conc	Units	Flag	Detected	Aroclor or Congener Count	Total PCB Type	Location Latitude	Location Longitude	Comment
SRRTTF-2015	L23783-37	SRRTTF_SR9	Post Falls Dam to Upriver Dam	8/22/2015	2015	FD	L23783-36	0.000144	ppb		Yes	159	TotPCBcong	47.6784	-117.1534	
SRRTTF-2015	L23783-41	SRRTTF_SR7	Post Falls Dam to Upriver Dam	8/22/2015	2015	S		0.000227	ppb		Yes	159	TotPCBcong	47.6971	-117.2418	
SRRTTF-2015	L23783-45	SRRTTF_SR3	Upriver Dam to Nine Mile Dam	8/22/2015	2015	S		0.000248	ppb		Yes	159	TotPCBcong	47.6589	-117.4497	
SRRTTF-2015	L23783-46	SRRTTF_SR8a	Post Falls Dam to Upriver Dam	8/22/2015	2015	S		0.0000758	ppb		Yes	159	TotPCBcong	47.6792	-117.2137	
SRRTTF-2015	L23784-35	SRRTTF_SR3	Upriver Dam to Nine Mile Dam	8/18/2015	2015	S		0.000385	ppb		Yes	159	TotPCBcong	47.6589	-117.4497	
SRRTTF-2015	L23784-36	SRRTTF_SR4	Upriver Dam to Nine Mile Dam	8/18/2015	2015	S		0.000283	ppb		Yes	159	TotPCBcong	47.6781	-117.3628	
SRRTTF-2015	L23784-39	SRRTTF_SR7	Post Falls Dam to Upriver Dam	8/18/2015	2015	S		0.000211	ppb		Yes	159	TotPCBcong	47.6971	-117.2418	
SRRTTF-2015	L23784-41	SRRTTF_SR8a	Post Falls Dam to Upriver Dam	8/18/2015	2015	S		0.0000652	ppb		Yes	159	TotPCBcong	47.6792	-117.2137	
SRRTTF-2015	L23784-42	SRRTTF_SR9	Post Falls Dam to Upriver Dam	8/18/2015	2015	S		0.000105	ppb		Yes	159	TotPCBcong	47.6784	-117.1534	
SRRTTF-2015	L24230-1	SRRTTF_SR4	Upriver Dam to Nine Mile Dam	8/22/2015	2015	S		0.00022	ppb		Yes	159	TotPCBcong	47.6781	-117.3628	
SRRTTF-2015	L24358-10	SRRTTF_SR4	Upriver Dam to Nine Mile Dam	8/19/2015	2015	S		0.000265	ppb		Yes	159	TotPCBcong	47.6781	-117.3628	
SRRTTF-2015	L24358-3	SRRTTF_SR7	Post Falls Dam to Upriver Dam	8/18/2015	2015	S		0.000259	ppb		Yes	159	TotPCBcong	47.6971	-117.2418	
SRRTTF-2015	L24358-4	SRRTTF_SR4	Upriver Dam to Nine Mile Dam	8/18/2015	2015	S		0.000265	ppb		Yes	159	TotPCBcong	47.6781	-117.3628	
SRRTTF-2015	L24358-5	SRRTTF_SR9	Post Falls Dam to Upriver Dam	8/18/2015	2015	S		0.0000952	ppb		Yes	159	TotPCBcong	47.6784	-117.1534	
SRRTTF-2015	L24358-6	SRRTTF_SR8a	Post Falls Dam to Upriver Dam	8/18/2015	2015	S		0.000295	ppb		Yes	159	TotPCBcong	47.6792	-117.2137	
SRRTTF-2015	L24358-8	SRRTTF_SR3	Upriver Dam to Nine Mile Dam	8/18/2015	2015	S		0.000274	ppb		Yes	159	TotPCBcong	47.6589	-117.4497	
SRRTTF-2015	L24358-9	SRRTTF_SR3	Upriver Dam to Nine Mile Dam	8/19/2015	2015	S		0.000231	ppb		Yes	159	TotPCBcong	47.6589	-117.4497	
SRRTTF-2016	L24941-3	SRRTTF_SR9	Post Falls Dam to Upriver Dam	4/19/2016	2016	S		0.0000345	ppb		Yes	159	TotPCBcong	47.6784	-117.1534	
SRRTTF-2016	L24941-4	SRRTTF_SR9	Post Falls Dam to Upriver Dam	4/19/2016	2016	FD	L24941-3	0.0000391	ppb		Yes	159	TotPCBcong	47.6784	-117.1534	
SRRTTF-2016	L24941-5	SRRTTF_SR4	Upriver Dam to Nine Mile Dam	4/19/2016	2016	S		0.000102	ppb		Yes	159	TotPCBcong	47.6781	-117.3628	
SRRTTF-2016	L24941-7	SRRTTF_SR3	Upriver Dam to Nine Mile Dam	4/19/2016	2016	S		0.0000795	ppb		Yes	159	TotPCBcong	47.6589	-117.4497	
SRRTTF-2016	L24941-8	SRRTTF_SR1	Nine Mile Dam to Long Lake Dam	4/19/2016	2016	S		0.0000871	ppb		Yes	159	TotPCBcong	47.7830	-117.5448	

Table B-2b. Concentrations of Total PCBs in Surface Water Samples Collected from the Spokane River

Study ID	Sample ID	Location ID	Reach	Date Collected	Year Collected	Sample Type	Parent Sample	Conc	Units	Flag	Detected	Aroclor or Congener Count	Total PCB Type	Location Latitude	Location Longitude	Comment
SRRTTF-2016	L25116-3	SRRTTF_SR7	Post Falls Dam to Upriver Dam	3/24/2016	2016	S		0.000084	ppb		Yes	159	TotPCBcong	47.6971	-117.2418	
SRRTTF-2016	L25116-4	SRRTTF_SR4	Upriver Dam to Nine Mile Dam	3/24/2016	2016	S		0.000105	ppb		Yes	159	TotPCBcong	47.6781	-117.3628	
SRRTTF-2016	L25116-6	SRRTTF_SR3	Upriver Dam to Nine Mile Dam	3/24/2016	2016	S		0.000094	ppb		Yes	159	TotPCBcong	47.6589	-117.4497	
SRRTTF-2016	L25116-7	SRRTTF_SR1	Nine Mile Dam to Long Lake Dam	3/24/2016	2016	S		0.000123	ppb		Yes	159	TotPCBcong	47.7830	-117.5448	
SRRTTF-2016	L25153-3	SRRTTF_SR7	Post Falls Dam to Upriver Dam	5/24/2016	2016	S		0.000163	ppb		Yes	159	TotPCBcong	47.6971	-117.2418	
SRRTTF-2016	L25153-4	SRRTTF_SR4	Upriver Dam to Nine Mile Dam	5/24/2016	2016	S		0.000141	ppb		Yes	159	TotPCBcong	47.6781	-117.3628	
SRRTTF-2016	L25153-6	SRRTTF_SR4	Upriver Dam to Nine Mile Dam	5/24/2016	2016	FD	L25153-4	0.000104	ppb		Yes	159	TotPCBcong	47.6781	-117.3628	
SRRTTF-2016	L25153-5	SRRTTF_SR1	Nine Mile Dam to Long Lake Dam	5/24/2016	2016	S		0.000215	ppb		Yes	159	TotPCBcong	47.7830	-117.5448	
SRRTTF-2016	L25153-7	SRRTTF_SR3	Upriver Dam to Nine Mile Dam	5/24/2016	2016	S		0.000136	ppb		Yes	159	TotPCBcong	47.6589	-117.4497	
SRRTTF-2016	L25297-2	SRRTTF_SR1	Nine Mile Dam to Long Lake Dam	6/16/2016	2016	S		0.000159	ppb		Yes	159	TotPCBcong	47.7830	-117.5448	
SRRTTF-2016	L25297-4	SRRTTF_SR3	Upriver Dam to Nine Mile Dam	6/16/2016	2016	S		0.000151	ppb		Yes	159	TotPCBcong	47.6589	-117.4497	
SRRTTF-2016	L25297-5	SRRTTF_SR3	Upriver Dam to Nine Mile Dam	6/16/2016	2016	FD	L25297-4	0.00015	ppb		Yes	159	TotPCBcong	47.6589	-117.4497	
SRRTTF-2016	L25297-6	SRRTTF_SR4	Upriver Dam to Nine Mile Dam	6/16/2016	2016	S		0.000153	ppb		Yes	159	TotPCBcong	47.6781	-117.3628	
SRRTTF-2016	L25297-7	SRRTTF_SR7	Post Falls Dam to Upriver Dam	6/16/2016	2016	S		0.000145	ppb		Yes	159	TotPCBcong	47.6971	-117.2418	
SRRTTF-2016	L26175-3	SRRTTF_SR7	Post Falls Dam to Upriver Dam	10/26/2016	2016	S		0.000104	ppb		Yes	159	TotPCBcong	47.6971	-117.2418	
SRRTTF-2016	L26175-4	SRRTTF_SR4	Upriver Dam to Nine Mile Dam	10/26/2016	2016	S		0.000186	ppb		Yes	159	TotPCBcong	47.6781	-117.3628	
SRRTTF-2016	L26175-5	SRRTTF_SR1	Nine Mile Dam to Long Lake Dam	10/26/2016	2016	S		0.000157	ppb		Yes	159	TotPCBcong	47.7830	-117.5448	
SRRTTF-2016	L26175-6	SRRTTF_SR1	Nine Mile Dam to Long Lake Dam	10/26/2016	2016	FD	L26175-5	0.000151	ppb		Yes	159	TotPCBcong	47.7830	-117.5448	
SRRTTF-2016	L26175-7	SRRTTF_SR3	Upriver Dam to Nine Mile Dam	10/26/2016	2016	S		0.00026	ppb		Yes	159	TotPCBcong	47.6589	-117.4497	
SRRTTF-2016	L26749-2	SRRTTF_SR7	Post Falls Dam to Upriver Dam	12/13/2016	2016	S		0.000289	ppb		Yes	159	TotPCBcong	47.6971	-117.2418	
SRRTTF-2016	L26749-3	SRRTTF_SR4	Upriver Dam to Nine Mile Dam	12/13/2016	2016	S		0.000202	ppb		Yes	159	TotPCBcong	47.6781	-117.3628	
SRRTTF-2016	L26749-4	SRRTTF_SR1	Nine Mile Dam to Long Lake Dam	12/13/2016	2016	S		0.000235	ppb		Yes	159	TotPCBcong	47.7830	-117.5448	

Table B-2b. Concentrations of Total PCBs in Surface Water Samples Collected from the Spokane River

Study ID	Sample ID	Location ID	Reach	Date Collected	Year Collected	Sample Type	Parent Sample	Conc	Units	Flag	Detected	Aroclor or Congener Count	Total PCB Type	Location Latitude	Location Longitude	Comment
SRRTTF-2016	L26749-6	SRRTTF_SR3	Upriver Dam to Nine Mile Dam	12/13/2016	2016	S		0.000217	ppb		Yes	159	TotPCBcong	47.6589	-117.4497	
SRRTTF-2016	L26471-2 i	SRRTTF_SR3	Upriver Dam to Nine Mile Dam	12/13/2016	2016	FD	L26749-6	0.000135	ppb		Yes	159	TotPCBcong	47.6589	-117.4497	
WHOB003	1606035-18	UGM	Long Lake Dam to Lake Roosevelt	6/10/2016	2016	S		0.0000221	ppb		Yes	159	TotPCBcong	47.8451	-117.8651	
WHOB003	1606035-19	UGM	Long Lake Dam to Lake Roosevelt	6/10/2016	2016	S		0.00000868	ppb		Yes	159	TotPCBcong	47.8451	-117.8651	
WHOB003	1606035-23	UGM	Long Lake Dam to Lake Roosevelt	6/10/2016	2016	S		0.00000624	ppb		Yes	159	TotPCBcong	47.8451	-117.8651	
WHOB003	1606035-24	UGM	Long Lake Dam to Lake Roosevelt	6/10/2016	2016	S		9.14E-07	ppb		Yes	159	TotPCBcong	47.8451	-117.8651	
WHOB003	1606035-25	UGM	Long Lake Dam to Lake Roosevelt	6/10/2016	2016	S		0.00000306	ppb		Yes	159	TotPCBcong	47.8451	-117.8651	
WHOB003	1702027-20	UGM	Long Lake Dam to Lake Roosevelt	2/9/2017	2017	S		0.0000203	ppb		Yes	159	TotPCBcong	47.8451	-117.8651	
WHOB003	1702027-21	UGM	Long Lake Dam to Lake Roosevelt	2/9/2017	2017	S		0.0000219	ppb		Yes	159	TotPCBcong	47.8451	-117.8651	
WHOB003	1702027-22	UGM	Long Lake Dam to Lake Roosevelt	2/9/2017	2017	S		0.0000244	ppb		Yes	159	TotPCBcong	47.8451	-117.8651	
WHOB003	1702027-24	UGM	Long Lake Dam to Lake Roosevelt	2/9/2017	2017	S		0.000032	ppb		Yes	159	TotPCBcong	47.8451	-117.8651	
WHOB003	1702027-25	UGM	Long Lake Dam to Lake Roosevelt	2/9/2017	2017	S		0.0000247	ppb		Yes	159	TotPCBcong	47.8451	-117.8651	

Notes:

For non-detect results the maximum detection limit for the congeners is used as the Total PCBs detection limit.

S = sample; FD = field duplicate

Sample-Duplicate pairs were averaged for the EPC calculations, but are shown separately in this table.

Total PCB Types: TotPCBar = Based on sum of detected Aroclor PCBs; TotPCBcong = Based on sum of detected PCB congeners.

[1] Concentration shown is maximum of reported congener-specific detection limits in this sample.

[2] This non-detect TotPCBar result was excluded from the EPC calculations because the detection limit (0.021 ppb) was well above the detected TotPCBcong concentrations and would result in an overly biased high and non-representative EPC calculation.

[3] Sample was identified as a field duplicate in EIMS but the parent sample was not reported. Treated as single sample result for EPC calculations.

Table B-2c. Summary of Total PCBs Concentrations for Surface Water Samples Collected from the Spokane River by Reach

							ProUCL Output			
Reaches	Collection Years	Frequency of Detection	Arithmetic Mean	Range of Detects	Range of Non-Detects	Congener Count Range	Distribution Type	KM Mean	Recommended UCL	UCL Type
Spokane River - Riverwide	2003, 2012 to 2017	122/125	0.000153	0.000130 to 0.000434	0.0000409 to 0.000556	150 to 187	Approximate Normal	0.000143	0.000156	95% KM (t) UCL
Post Falls Dam to Upriver Dam	2003, 2012 to 2016	50/53	0.000129	0.0000246 to 0.000434	0.0000409 to 0.000556	150 to 187	Gamma	0.000124	0.000144	95% KM Approximate Gamma UCL
Upriver Dam to Nine Mile Dam	2003, 2012 to 2016	45/45	0.000189	0.0000169 to 0.000418	---	159 to 187	Normal	NC	0.000209	95% Student's-t UCL
Nine Mile Dam to Long Lake Dam	2014 and 2016	14/14	0.000183	0.0000871 to 0.000245	---	159 to 159	Normal	NC	0.000203	95% Student's-t UCL
Long Lake Dam to Lake Roosevelt	2012, 2013, 2016 and 2017	13/13	0.0000197	0.000000914 to 0.000048	---	159 to 187	Normal	NC	0.0000262	95% Student's-t UCL

Notes:

All concentration units are in ppb.

Total PCBs are based on the sum of the detected PCB congeners.

Washington State Riverwide summarizes across the four river reaches in the Washington State portion of the Spokane River.

Arithmetic Mean is calculated by setting non-detect results to one-half the reporting limits.

A dash ('---") indicates that the value was not calculated or not required.

NC = Not calculated. The KM Mean is calculated only when the detection frequency is less than 100%.

ppb = parts per billion

UCL = upper confidence limit

Table B-3a. Summary of Ecology Studies, Collection Years, and Analytical Methods for Surface Sediment PCBs

EIM Study ID	Description	Analytical Method	Aroclor PCBs	PCB Congeners	Collection Years	Comment
BERA0009	Spokane River Toxics Preliminary Monitoring 2012 through 2013 - In Support of the Long-term Toxics Monitoring Strategy	EPA 1668C		◆	2012 and 2013	Excluded - See Note [1]
BERA0012	Spokane River PCBs and Other Toxics: Long-Term Monitoring at the Spokane Tribal Boundary	EPA 1668C		◆	2015 and 2016	Excluded - See Note [1]
DSER0010	Spokane River PCB Source Assessment 2003-2007 (formerly Spokane River PCB TMDL)	SW 8082	◆		2003 and 2004	Reported results for 9 Aroclor PCBs.
		EPA 1668A		◆	2003 and 2004	Reported results for 163 PCB congeners or congener groups.
SRUW-Spokane	Spokane River Urban Waters-Spokane River Source Trace Study Regarding PCB, PBDE, Metal, and Dioxin/Furan Contamination	SW 8082	◆		2010 to 2013	Reported results for 9 Aroclor PCBs.
		EPA 1668C		◆	2010 to 2013	Reported results for 159 to 182 PCB congeners or congener groups.
UPRVRDAM	Upriver Dam PCB Sediments Site	SW 8082	◆		2003 and 2004	Reported results for 1 Aroclor PCB.
WHOB003	Assessment of Methods for Sampling Low-Level Toxics in Surface Waters	EPA 1668C		◆	2016 and 2017	Excluded - See Note [2]

Notes:

Descriptions from Ecology EIM database (https://ecology.wa.gov/Research-Data/Data-resources/Environmental-Information-Management-database).

Ecology = Washington State Department of Ecology

EIM = Environmental Information Management System

EPA = U.S. Environmental Protection Agency

PCB = polychlorinated biphenyl

PBDE = polybrominated diphenyl ether

TMDL = total maximum daily load

[1] EIM Study IDs BERA0009 and BERA0012 reported results from settleable solids collected using sediment traps. Excluded from this assessment because this does not represent a river-related surface sediment exposure.

[2] EIM Study ID WHOB003 reported results for suspended sediments removed by centrifugation from surface water samples. Excluded from this assessment because this does not represent a river-related surface sediment exposure.

Table B-3b. Concentrations of Total PCBs in Surface Sediment Samples Collected from the Spokane River

Study ID	Sample ID	Location ID	Depth Interval (cm)	SubArea	Date Collected	Year Collected	Sample Type	Parent Sample	Conc	Units	Flag	Detected	Aroclor or Congener Count	Total PCBs Type	Location Latitude	Location Longitude	Comment
DSER0010	3438100	HARVARD	NR	Post Falls Dam to Upriver Dam	10/20/2003	2003	S		9.60	ppb_{dw}		Yes	163	TotPCBcong	47.6837	-117.1104	
DSER0010	3448100	PLANTEFRY	NR	Post Falls Dam to Upriver Dam	10/28/2003	2003	S		7.09	ppb_{dw}		Yes	163	TotPCBcong	47.6976	-117.2456	
DSER0010	3454105	NINEM SPM	NR	Upriver Dam to Nine Mile Dam	11/3/2003	2003	S		68.8	ppb_{dw}		Yes	163	TotPCBcong	47.7264	-117.5131	
DSER0010	3454111	LongLkMid	0 to 2	Nine Mile Dam to Long Lake Dam	11/4/2003	2003	S		24.4	ppb_{dw}		Yes	163	TotPCBcong	47.8859	-117.6922	
DSER0010	3454112	LONGLKLOW	0 to 2	Nine Mile Dam to Long Lake Dam	11/4/2003	2003	S		29.2	ppb_{dw}		Yes	163	TotPCBcong	47.8288	-117.7700	
DSER0010	3454113	Littlefls	0 to 2	Long Lake Dam to Lake Roosevelt	11/4/2003	2003	S		1.90	ppb_{dw}		Yes	163	TotPCBcong	47.8360	-117.9116	
DSER0010	3454114	LONGLKLOW	0 to 2	Nine Mile Dam to Long Lake Dam	11/4/2003	2003	S		23.5	ppb_{dw}		Yes	163	TotPCBcong	47.8288	-117.7700	
DSER0010	4168149	MonroeSed	0 to 2	Upriver Dam to Nine Mile Dam	4/14/2004	2004	S		6.17	ppb_{dw}		Yes	163	TotPCBcong	47.6642	-117.4070	
DSER0010	4208147	LongLkUp	0 to 2	Nine Mile Dam to Long Lake Dam	5/11/2004	2004	S		49.7	ppb_{dw}		Yes	163	TotPCBcong	47.7937	-117.5708	
DSER0010	04268372	LONGLOW2	0 to 1	Nine Mile Dam to Long Lake Dam	11/4/2003	2003	S		28.0	ppb_{dw}		Yes	9	TotPCBar	47.8154	-117.8080	
DSER0010	04268373	LONGLOW2	1 to 2	Nine Mile Dam to Long Lake Dam	11/4/2003	2003	S		75.0	ppb_{dw}		Yes	9	TotPCBar	47.8154	-117.8080	
DSER0010	04268374	LONGLOW2	3 to 4	Nine Mile Dam to Long Lake Dam	11/4/2003	2003	S		42.0	ppb_{dw}		Yes	9	TotPCBar	47.8154	-117.8080	
DSER0010	04268375	LONGLOW2	5 to 6	Nine Mile Dam to Long Lake Dam	11/4/2003	2003	S		40.0	ppb_{dw}		Yes	9	TotPCBar	47.8154	-117.8080	
DSER0010	04268376	LONGLOW2	7 to 8	Nine Mile Dam to Long Lake Dam	11/4/2003	2003	S		27.0	ppb_{dw}		Yes	9	TotPCBar	47.8154	-117.8080	
DSER0010	04268377	LONGLOW2	9 to 10	Nine Mile Dam to Long Lake Dam	11/4/2003	2003	S		32.1	ppb_{dw}		Yes	9	TotPCBar	47.8154	-117.8080	
DSER0010	04268378	LONGLOW2	11 to 12	Nine Mile Dam to Long Lake Dam	11/4/2003	2003	S		54.0	ppb_{dw}		Yes	9	TotPCBar	47.8154	-117.8080	
DSER0010	04268379	LONGLOW2	14 to 15	Nine Mile Dam to Long Lake Dam	11/4/2003	2003	S		59.0	ppb_{dw}		Yes	9	TotPCBar	47.8154	-117.8080	
DSER0010	04268382	LONGUP2	0 to 1	Nine Mile Dam to Long Lake Dam	6/9/2004	2004	S		7.8	ppb_{dw}		Yes	9	TotPCBar	47.8349	-117.6519	
DSER0010	04268383	LONGUP2	1 to 2	Nine Mile Dam to Long Lake Dam	6/9/2004	2004	S		13.8	ppb_{dw}		Yes	9	TotPCBar	47.8349	-117.6519	
DSER0010	04268384	LONGUP2	3 to 4	Nine Mile Dam to Long Lake Dam	6/9/2004	2004	S		15.9	ppb_{dw}		Yes	9	TotPCBar	47.8349	-117.6519	
DSER0010	04268385	LONGUP2	5 to 6	Nine Mile Dam to Long Lake Dam	6/9/2004	2004	S		16.2	ppb_{dw}		Yes	9	TotPCBar	47.8349	-117.6519	
DSER0010	04268386	LONGUP2	7 to 8	Nine Mile Dam to Long Lake Dam	6/9/2004	2004	S		19.2	ppb_{dw}		Yes	9	TotPCBar	47.8349	-117.6519	
DSER0010	04268387	LONGUP2	9 to 10	Nine Mile Dam to Long Lake Dam	6/9/2004	2004	S		33.3	ppb_{dw}		Yes	9	TotPCBar	47.8349	-117.6519	
DSER0010	04268388	LONGUP2	11 to 12	Nine Mile Dam to Long Lake Dam	6/9/2004	2004	S		32.0	ppb_{dw}		Yes	9	TotPCBar	47.8349	-117.6519	
DSER0010	04268389	LONGUP2	14 to 15	Nine Mile Dam to Long Lake Dam	6/9/2004	2004	S		28.0	ppb_{dw}		Yes	9	TotPCBar	47.8349	-117.6519	
DSER0010	3458100-S	SPOK-1	0 to 2	Long Lake Dam to Lake Roosevelt	11/6/2003	2003	S		10.4	ppb_{dw}		Yes	163	TotPCBcong	47.8839	-118.1508	
SRUW-Spokane	1308073-01	Dam-11	NR	Upriver Dam to Nine Mile Dam	8/27/2013	2013	S		2.48	ppb_{dw}		Yes	182	TotPCBcong	47.6825	-117.3322	
SRUW-Spokane	1308073-01REX	Dam-11	NR	Upriver Dam to Nine Mile Dam	8/27/2013	2013	S		2.92	ppb_{dw}		Yes	182	TotPCBcong	47.6825	-117.3322	[1]
SRUW-Spokane	1308073-02	WaterW-10	NR	Upriver Dam to Nine Mile Dam	8/27/2013	2013	S		2.44	ppb_{dw}		Yes	182	TotPCBcong	47.6794	-117.3360	
SRUW-Spokane	1308073-04	Sup-5	NR	Upriver Dam to Nine Mile Dam	8/27/2013	2013	S		16.4	ppb_{dw}		Yes	182	TotPCBcong	47.6660	-117.3920	
SRUW-Spokane	1308073-05	StoneSt-8	NR	Upriver Dam to Nine Mile Dam	8/27/2013	2013	S		15.5	ppb_{dw}		Yes	182	TotPCBcong	47.6785	-117.3762	
SRUW-Spokane	1308073-06	Dam-11	NR	Upriver Dam to Nine Mile Dam	8/27/2013	2013	S		3.41	ppb_{dw}		Yes	182	TotPCBcong	47.6825	-117.3322	
SRUW-Spokane	1308073-06REX	Dam-11	NR	Upriver Dam to Nine Mile Dam	8/27/2013	2013	S		4.11	ppb_{dw}		Yes	182	TotPCBcong	47.6825	-117.3322	[1]
SRUW-Spokane	1308073-10	Dam-13	NR	Upriver Dam to Nine Mile Dam	8/29/2013	2013	S		2.47	ppb_{dw}		Yes	182	TotPCBcong	47.6815	-117.3329	
SRUW-Spokane	1308073-12	Avi-6	NR	Upriver Dam to Nine Mile Dam	8/29/2013	2013	S		10.4	ppb_{dw}		Yes	182	TotPCBcong	47.6753	-117.3852	
SRUW-Spokane	1308073-13	PostTerm2	NR	Upriver Dam to Nine Mile Dam	8/29/2013	2013	S		97.0	ppb_{dw}		Yes	9	TotPCBar	47.6601	-117.3978	
SRUW-Spokane	1308073-13	PostTerm	NR	Upriver Dam to Nine Mile Dam	8/29/2013	2013	S		40.8	ppb_{dw}		Yes	182	TotPCBcong	47.6601	-117.3978	[2]
UPRVRDAM	AN-10SD-A	UPRVRDAMAN-10	0 to 10	Post Falls Dam to Upriver Dam	9/3/2003	2003	S		28.0	ppb_{dw}		Yes	7	TotPCBar	47.6902	-117.3170	
UPRVRDAM	AN-11SD-A	UPRVRDAMAN-11	0 to 10	Post Falls Dam to Upriver Dam	9/6/2003	2003	S		2.1	ppb_{dw}	U	No	7	TotPCBar	47.6910	-117.3162	
UPRVRDAM	AN-12SD-A	UPRVRDAMAN-12	0 to 10	Post Falls Dam to Upriver Dam	9/6/2003	2003	S		2.5	ppb_{dw}	U	No	7	TotPCBar	47.6915	-117.3156	
UPRVRDAM	AN-13SD-A	UPRVRDAMAN-13	0 to 10	Post Falls Dam to Upriver Dam	9/6/2003	2003	S		2.3	ppb_{dw}	U	No	7	TotPCBar	47.6942	-117.3088	
UPRVRDAM	AN-14SD-A	UPRVRDAMAN-14	0 to 10	Post Falls Dam to Upriver Dam	9/3/2003	2003	S		2.8	ppb_{dw}	U	No	7	TotPCBar	47.6896	-117.2667	

Table B-3b. Concentrations of Total PCBs in Surface Sediment Samples Collected from the Spokane River

Study ID	Sample ID	Location ID	Depth Interval (cm)	SubArea	Date Collected	Year Collected	Sample Type	Parent Sample	Conc	Units	Flag	Detected	Aroclor or Congener Count	Total PCBs Type	Location Latitude	Location Longitude	Comment
UPRVRDAM	AN-15SD-A	UPRVRDAMAN-15	0 to 10	Post Falls Dam to Upriver Dam	9/3/2003	2003	S		20.0	ppb_{dw}		Yes	7	TotPCBar	47.6897	-117.2663	
UPRVRDAM	AN-20SD-A	UPRVRDAMAN-20	0 to 10	Post Falls Dam to Upriver Dam	9/6/2003	2003	S		3.4	ppb_{dw}		Yes	7	TotPCBar	47.6859	-117.3265	
UPRVRDAM	AN-21SD-A	UPRVRDAMAN-21	0 to 10	Post Falls Dam to Upriver Dam	9/6/2003	2003	S		3.0	ppb_{dw}		Yes	7	TotPCBar	47.6861	-117.3255	
UPRVRDAM	AN-22SD-A	UPRVRDAMAN-22	0 to 10	Post Falls Dam to Upriver Dam	9/6/2003	2003	S		5.3	ppb_{dw}		Yes	7	TotPCBar	47.6865	-117.3242	
UPRVRDAM	AN-23SD-A	UPRVRDAMAN-23	0 to 10	Post Falls Dam to Upriver Dam	9/6/2003	2003	S		2.6	ppb_{dw}		Yes	7	TotPCBar	47.6869	-117.3224	
UPRVRDAM	AN-24SD-A	UPRVRDAMAN-24	0 to 10	Post Falls Dam to Upriver Dam	9/6/2003	2003	S		3.4	ppb_{dw}		Yes	7	TotPCBar	47.6875	-117.3210	
UPRVRDAM	AN-25SD-A	UPRVRDAMAN-25	0 to 10	Post Falls Dam to Upriver Dam	9/6/2003	2003	S		33.0	ppb_{dw}		Yes	7	TotPCBar	47.6885	-117.3194	
UPRVRDAM	AN-26SD-A	UPRVRDAMAN-26	0 to 10	Post Falls Dam to Upriver Dam	9/6/2003	2003	S		2.4	ppb_{dw}	U	No	7	TotPCBar	47.6891	-117.3190	
UPRVRDAM	AN-27SD-A	UPRVRDAMAN-27	0 to 10	Post Falls Dam to Upriver Dam	9/6/2003	2003	S		8.2	ppb_{dw}		Yes	7	TotPCBar	47.6879	-117.3188	
UPRVRDAM	AN-28SD-A	UPRVRDAMAN-28	0 to 10	Post Falls Dam to Upriver Dam	9/3/2003	2003	S		2.1	ppb_{dw}	U	No	7	TotPCBar	47.6886	-117.3182	
UPRVRDAM	AN-29SD-A	UPRVRDAMAN-29	0 to 10	Post Falls Dam to Upriver Dam	9/6/2003	2003	S		3.2	ppb_{dw}		Yes	7	TotPCBar	47.6896	-117.3174	
UPRVRDAM	AN-30SD-A	UPRVRDAMAN-30	0 to 10	Post Falls Dam to Upriver Dam	9/5/2003	2003	S		6.8	ppb_{dw}		Yes	7	TotPCBar	47.6925	-117.3136	
UPRVRDAM	AN-31SD-A	UPRVRDAMAN-31	0 to 10	Post Falls Dam to Upriver Dam	9/5/2003	2003	S		2.4	ppb_{dw}		Yes	7	TotPCBar	47.6930	-117.3119	
UPRVRDAM	AN-32SD-A	UPRVRDAMAN-32	0 to 10	Post Falls Dam to Upriver Dam	9/6/2003	2003	S		2.2	ppb_{dw}	U	No	7	TotPCBar	47.6934	-117.3098	
UPRVRDAM	AN-40SD-A	UPRVRDAMAN-40	0 to 10	Post Falls Dam to Upriver Dam	9/3/2003	2003	S		330	ppb_{dw}		Yes	7	TotPCBar	47.6905	-117.2643	
UPRVRDAM	AN-41SD-A	UPRVRDAMAN-41	0 to 10	Post Falls Dam to Upriver Dam	9/3/2003	2003	S		79.0	ppb_{dw}		Yes	7	TotPCBar	47.6901	-117.2644	
UPRVRDAM	AN-42SD-A	UPRVRDAMAN-42	0 to 10	Post Falls Dam to Upriver Dam	9/3/2003	2003	S		25.0	ppb_{dw}		Yes	7	TotPCBar	47.6905	-117.2640	
UPRVRDAM	AN-61SD-A	UPRVRDAMAN-11	0 to 10	Post Falls Dam to Upriver Dam	9/6/2003	2003	S		10.0	ppb_{dw}		Yes	7	TotPCBar	47.6910	-117.3162	
UPRVRDAM	AN-70SD-A	UPRVRDAMAN-20	0 to 10	Post Falls Dam to Upriver Dam	9/6/2003	2003	S		4.4	ppb_{dw}		Yes	7	TotPCBar	47.6859	-117.3265	
UPRVRDAM	AN-81SD-A	UPRVRDAMAN-31	0 to 10	Post Falls Dam to Upriver Dam	9/5/2003	2003	S		2.3	ppb_{dw}		Yes	7	TotPCBar	47.6930	-117.3119	
UPRVRDAM	BWE-9	UPRVRDAMBWE-9	0 to 10	Post Falls Dam to Upriver Dam	9/4/2003	2003	S		260	ppb_{dw}		Yes	7	TotPCBar	47.6863	-117.3278	
UPRVRDAM	UPR103041007	UPRVRDAMUPR-53	NR	Post Falls Dam to Upriver Dam	10/7/2004	2004	S		42.0	ppb_{dw}		Yes	7	TotPCBar	47.6906	-117.3164	
UPRVRDAM	UPR51-041007	UPRVRDAMUPR-51	NR	Post Falls Dam to Upriver Dam	10/7/2004	2004	S		26.0	ppb_{dw}		Yes	7	TotPCBar	47.6904	-117.3167	
UPRVRDAM	UPR52-041007	UPRVRDAMUPR-52	NR	Post Falls Dam to Upriver Dam	10/7/2004	2004	S		9.7	ppb_{dw}	U	No	7	TotPCBar	47.6907	-117.3166	
UPRVRDAM	UPR53-041007	UPRVRDAMUPR-53	NR	Post Falls Dam to Upriver Dam	10/7/2004	2004	S		40.0	ppb_{dw}		Yes	7	TotPCBar	47.6906	-117.3164	
UPRVRDAM	UPR54-041007	UPRVRDAMUPR-54	NR	Post Falls Dam to Upriver Dam	10/7/2004	2004	S		11.0	ppb_{dw}		Yes	7	TotPCBar	47.6908	-117.3163	
UPRVRDAM	UPR55-041007	UPRVRDAMUPR-55	NR	Post Falls Dam to Upriver Dam	10/7/2004	2004	S		9.6	ppb_{dw}	U	No	7	TotPCBar	47.6899	-117.2658	
UPRVRDAM	UPR56-041007	UPRVRDAMUPR-56	NR	Post Falls Dam to Upriver Dam	10/7/2004	2004	S		9.9	ppb_{dw}	U	No	7	TotPCBar	47.6901	-117.2652	
UPRVRDAM	UPR57-041007	UPRVRDAMUPR-57	NR	Post Falls Dam to Upriver Dam	10/7/2004	2004	S		9.8	ppb_{dw}	U	No	7	TotPCBar	47.6903	-117.2647	
UPRVRDAM	UPR58-041007	UPRVRDAMUPR-58	NR	Post Falls Dam to Upriver Dam	10/7/2004	2004	S		46.0	ppb_{dw}		Yes	7	TotPCBar	47.6898	-117.2655	
UPRVRDAM	UPR59-041007	UPRVRDAMUPR-59	NR	Post Falls Dam to Upriver Dam	10/7/2004	2004	S		9.8	ppb_{dw}	U	No	7	TotPCBar	47.6899	-117.2649	
UPRVRDAM	UPR60-041007	UPRVRDAMUPR-60	NR	Post Falls Dam to Upriver Dam	10/7/2004	2004	S		13.0	ppb_{dw}		Yes	7	TotPCBar	47.6902	-117.2642	
UPRVRDAM	UPR61-041007	UPRVRDAMUPR-61	NR	Post Falls Dam to Upriver Dam	10/7/2004	2004	S		9.7	ppb_{dw}	U	No	7	TotPCBar	47.6903	-117.2640	

Notes:

NR = Depth interval not reported in EIMS. Confirmed that samples represented grab samples based on review of other Ecology documentation.

Ecology = Washington State Department of Ecology

EIM = Environmental Information Management System

PCB = polychlorinated biphenyl

ppb_{dw} = parts per billion dry weight

Sample Types: S = Sample. There were no field duplicates in these data sets.

Samples with multiple collection depths were depth averaged for EPC calculations.

[1] Samples were re-extracted by the laboratory. Both the original and re-extracted results were reported in the EIMS data set (due to sample non-homogeneity) so both were retained as independent samples.

[2] Results for total PCBs based on sum of PCB congeners is shown for sample PostTerm but the total PCBs based on sum of PCB congeners were used for EPC development.

Table B-3c. Summary of Total PCBs Concentrations in Surface Sediments from the Spokane River by Reach and ProUCL Outputs

	Summary Statistics				ProUCL Output				
River Area	Frequency of Detection	Arithmetic Mean	Range of Positive Results	Range of Detection Limits for Non-Detect Results	Distribution Type	KM Mean[a]	Mean Type	95UCL[b]	Basis for 95UCL Recommended by ProUCL
Spokane River Only	48/61	25.2	1.90 to 330	2.1 to 9.9	Approximate Lognormal	8.86	KM Geomean	32.5	95% H-UCL (KM -Log)
Post Falls Dam to Upriver Dam	27/40	26.6	2.3 to 330	2.1 to 9.9	Lognormal	7.72	KM Geomean	36.0	95% H-UCL (KM -Log)
Upriver Dam to Nine Mile Dam	13/13	21.0	2.44 to 97	---	Approximate Gamma	---	---	47.4	95% Adjusted Gamma UCL
Nine Mile Dam to Long Lake Dam	6/6	32.0	20.8 to 49.7	---	Normal	---	---	42.0	95% Student's-t UCL
Long Lake Dam to Lake Roosevelt	2/2	6.15	1.9 to 10.4	---	NC	---	NC	NC	Maximum detection used as UCL

Notes:

All concentration units are in ppb_{dw}.

Half-DL Arithmetic Mean, KM Mean values and 95^{th}% UCL values are rounded to three significant digits in this table.

Total PCBs were based on the sum of the detected Aroclor PCBs or sum of detected PCB congeners.

Frequency of detection: The ratio of the counts of detected results and the total number of results.

A dash ('---") indicates that the value was not calculated or not required.

NC = No calculations. Due to small number of sample results and low detection frequency ProUCL did not perform any summary calculations.

PCB = plychlorinated biphenyl

UCL = upper confidence limit

[a] KM Mean is the Kaplan-Meier Mean concentration that was calculated by EPA's ProUCL software (v 5.1) when the detection frequency is less than 100%.

[b] The 95UCL is the 95^{th} percentile upper confidence limit for the arithmetic mean concentration that was calculated using EPA's ProUCL software (v 5.1).

Table B-4a. Summary of Ecology Studies, Collection Years, and Analytical Methods for Spokane River and Lake Roosevelt Gamefish Total PCBs

EIM Study ID	Description	Analytical Method	Aroclor PCBs	PCB Congeners	Collection Years	Comment
AJOH0063	Background Assessment for Chemical Contaminants in Northeastern Washington Area Lakes.	EPA1668A		◆	2010 and 2011	Excluded - see note [1]
BERA0011	Lake Spokane PCBs in Carp	SW8082A	◆		2014	Excluded - see note [1]
		EPA1668		◆		
DSER0010	Spokane River PCB Source Assessment 2003-2007 (formerly Spokane River PCB TMDL)	EPA1668A		◆	2003 and 2004	Retained
DSER0015	Persistent Organic Pollutants in Feed and Rainbow Trout from Selected Trout Hatcheries	SW8082	◆		2005	Excluded - see note [1]
DSER0016	PCBs, PBDEs, and Selected Metals in Spokane River Fish, 2005	SW8082	◆		2005	Retained
EPALAKES	National Study of Chemical Residues in Lake Fish Tissue (EPA)	EPA1656A	◆		2002	Excluded - see note [1]
		EPA1668A		◆		
EPALR05B	USEPA 2005 Phase 1 Fish Tissue Sampling: RI/FS Upper Columbia River/ Lake Roosevelt	CLP-OLM04.3	◆		2005	Retained
		EPA1668A		◆	2005	Retained
FFCMP13	Freshwater Fish Contaminant Monitoring Program 2013	SW8081/8082	◆		2013	Excluded - see note [1]
MIFR0002	Little Spokane River PCBs in Fish Tissue Verification Study	EPA1668C		◆	2014	Excluded - see note [1]
mifr0003	Spokane Fish Hatchery PCB Evaluation	EPA1668C		◆	2016	Excluded - see note [1]
RCOO0008	West Medical Lake PCBs, Dioxins and Furans in Fish, Sediment, and Wastewater Treatment Plant Effluent	SW8082	◆		2008	Excluded - see note [1]
RJAC002	Metals and PCBs in Long Lake Fish	SW8082	◆		2001	Retained
		EPA1668A		◆		
UCR_FS05	Phase I Upper Columbia River Site CERCLA RI/FS - Fish Tissue Data	SW8082	◆		2005	Excluded - see note [1]
		EPA1668		◆		
WSTMP01	Washington State Toxics Monitoring Program: Exploratory Monitoring 2001	SW8080	◆		2001	Excluded - see note [1]
WSTMP02	Washington State Toxics Monitoring Program: Exploratory Monitoring 2002	SW8081/8082	◆		2002	Excluded - see note [1]
WSTMP03	Washington State Toxics Monitoring Program: Exploratory Monitoring 2003.	SW8080, SW8081/8082	◆		2003	Excluded - see note [1]
WSTMP03T	Washington State Toxics Monitoring Program: Pre-QAPP Trend Monitoring	EPA1668A		◆	2003	Retained
WSTMP05	Washington State Toxics Monitoring Program: Exploratory Monitoring 2005.	SW8082	◆		2005	Excluded - see note [1]
		EPA1668A		◆		

Table B-4a. Summary of Ecology Studies, Collection Years, and Analytical Methods for Spokane River and Lake Roosevelt Gamefish Total PCBs

EIM Study ID	Description	Analytical Method	Aroclor PCBs	PCB Congeners	Collection Years	Comment
WSTMP06	Washington State Toxics Monitoring Program: Exploratory Monitoring 2006.	SW8081/8082	◆		2006	Excluded - see note [1]
		EPA1668A		◆		
WSTMP07	Washington State Toxics Monitoring Program: Exploratory Monitoring 2007.	SW8082	◆		2007	Excluded - see note [1]
		EPA1668A		◆		
WSTMP08	Washington State Toxics Monitoring Program: Exploratory Monitoring 2008.	SW8082	◆		2008	Excluded - see note [1]
		EPA1668A		◆		
WSTMP09	Washington State Toxics Monitoring Program: Exploratory Monitoring 2009.	SW8082	◆		2009	Excluded - see note [1]
WSTMP12	Washington State Toxics Monitoring Program: Exploratory Monitoring 2012	SW8082, SW8081/8082	◆		2012	Retained
		EPA1668C		◆		

Notes:

Descriptions from Ecology EIM database (https://ecology.wa.gov/Research-Data/Data-resources/Environmental-Information-Management-database).

Ecology = Washington State Department of Ecology

EIM = Environmenal Information Management Database

PCB = polychlorinated biphenyl

[1] Data set excluded because it does not include PCB results for evaluated gamefish species, reports results for other tissue types, or is for waterways outside of the assessment area.

Table B-4b. Summary of Spokane River and Lake Roosevelt PRA Gamefish Groups and Associated Species with Aroclor PCB or PCB Congener Data

		Spokane River Reaches				
PRA Gamefish Species or Group	Associated Species	Post Falls Dam to Upriver Dam	Upriver Dam to Nine Mile Dam	Nine Mile Dam to Long Lake Dam	Long Lake Dam to Lake Roosevelt	Lake Roosevelt
Bass group	Smallmouth bass			◆	◆	◆
	Largemouth bass				◆	
	White crappie			◆		
Perch group	Yellow perch			◆		
Salmon group	Mountain whitefish		◆	◆		
	Sockeye salmon				◆	◆
Trout group	Brown trout			◆	◆	
	Rainbow trout	◆	◆	◆	◆	◆
Walleye	Walleye					◆

Note:
Only the fillet/skin-on results were assessed.
PCB = polychlorinated biphenyl
PRA = probabilistic risk assessment

Table B-4c. Total PCBs Concentrations in PRA Gamefish Collected from the Spokane River and Lake Roosevelt

Study ID	Sample ID	Location ID	Reach	Fish Species Common Name	PRA Gamefish Group	Tissue Type	Date Collected	Year Collected	Sample Type	Parent Sample	Conc	Units	Flag	Aroclor or Congener Count	Detected	PCB Type	Location Latitude	Location Longitude
DSER0010	4188308	PLANTE-F	Post Falls Dam to Upriver Dam	Rainbow trout	Trout Group	Fillet/Skin-on	9/15/2003	2003	S		40.9	ppb_{ww}		163	Yes	TotPCBcong	47.694593	-117.2393447
DSER0010	4188309	PLANTE-F	Post Falls Dam to Upriver Dam	Rainbow trout	Trout Group	Fillet/Skin-on	9/15/2003	2003	S		28.4	ppb_{ww}		163	Yes	TotPCBcong	47.694593	-117.2393447
DSER0016	5494230	Spokane River (River Mile 85.0)	Post Falls Dam to Upriver Dam	Rainbow trout	Trout Group	Fillet/Skin-on	8/23/2005	2005	S		68	ppb_{ww}		9	Yes	TotPCBar	47.694978	-117.239903
DSER0016	5494231	Spokane River (River Mile 85.0)	Post Falls Dam to Upriver Dam	Rainbow trout	Trout Group	Fillet/Skin-on	8/23/2005	2005	S		48.6	ppb_{ww}		9	Yes	TotPCBar	47.694978	-117.239903
DSER0016	5494232	Spokane River (River Mile 85.0)	Post Falls Dam to Upriver Dam	Rainbow trout	Trout Group	Fillet/Skin-on	8/23/2005	2005	S		48	ppb_{ww}		9	Yes	TotPCBar	47.694978	-117.239903
DSER0016	5494233	Spokane River (River Mile 40.1)	Nine Mile Dam to Long Lake Dam	Mountain whitefish	Salmon Group	Fillet/Skin-on	11/3/2005	2005	S		41	ppb_{ww}		9	Yes	TotPCBar	47.834724	-117.736628
DSER0016	5494234	Spokane River (River Mile 40.1)	Nine Mile Dam to Long Lake Dam	Mountain whitefish	Salmon Group	Fillet/Skin-on	11/3/2005	2005	S		9.6	ppb_{ww}	U	9	No	TotPCBar	47.834724	-117.736628
DSER0016	5494235	Spokane River (River Mile 40.1)	Nine Mile Dam to Long Lake Dam	Mountain whitefish	Salmon Group	Fillet/Skin-on	11/3/2005	2005	S		16.3	ppb_{ww}		9	Yes	TotPCBar	47.834724	-117.736628
DSER0016	5494236	Spokane River (River Mile 40.1)	Nine Mile Dam to Long Lake Dam	Mountain whitefish	Salmon Group	Fillet/Skin-on	11/3/2005	2005	S		70.2	ppb_{ww}		9	Yes	TotPCBar	47.834724	-117.736628
DSER0016	5494237	Spokane River (River Mile 40.1)	Nine Mile Dam to Long Lake Dam	Mountain whitefish	Salmon Group	Fillet/Skin-on	11/3/2005	2005	S		130	ppb_{ww}		9	Yes	TotPCBar	47.834724	-117.736628
DSER0016	5494238	Spokane River (River Mile 40.1)	Nine Mile Dam to Long Lake Dam	Mountain whitefish	Salmon Group	Fillet/Skin-on	11/3/2005	2005	S		190	ppb_{ww}		9	Yes	TotPCBar	47.834724	-117.736628
DSER0016	5494239	Spokane River (River Mile 55.6)	Nine Mile Dam to Long Lake Dam	Mountain whitefish	Salmon Group	Fillet/Skin-on	9/27/2005	2005	S		55	ppb_{ww}		9	Yes	TotPCBar	47.80089	-117.548598
DSER0016	5494240	Spokane River (River Mile 55.6)	Nine Mile Dam to Long Lake Dam	Mountain whitefish	Salmon Group	Fillet/Skin-on	9/27/2005	2005	S		36	ppb_{ww}		9	Yes	TotPCBar	47.80089	-117.548598
DSER0016	5494241	Spokane River (River Mile 55.6)	Nine Mile Dam to Long Lake Dam	Mountain whitefish	Salmon Group	Fillet/Skin-on	9/27/2005	2005	S		38.4	ppb_{ww}		9	Yes	TotPCBar	47.80089	-117.548598
DSER0016	5494261	Spokane River (River Mile 75.2)	Upriver Dam to Nine Mile Dam	Rainbow trout	Trout Group	Fillet/Skin-on	9/28/2005	2005	S		220	ppb_{ww}		9	Yes	TotPCBar	47.664007	-117.404158
DSER0016	5494262	Spokane River (River Mile 75.2)	Upriver Dam to Nine Mile Dam	Rainbow trout	Trout Group	Fillet/Skin-on	9/28/2005	2005	S		121	ppb_{ww}		9	Yes	TotPCBar	47.664007	-117.404158
DSER0016	5494263	Spokane River (River Mile 75.2)	Upriver Dam to Nine Mile Dam	Rainbow trout	Trout Group	Fillet/Skin-on	9/28/2005	2005	S		118	ppb_{ww}		9	Yes	TotPCBar	47.664007	-117.404158
DSER0016	5494264	Spokane River (River Mile 77.0)	Upriver Dam to Nine Mile Dam	Mountain whitefish	Salmon Group	Fillet/Skin-on	9/28/2005	2005	S		280	ppb_{ww}		9	Yes	TotPCBar	47.676551	-117.382298
DSER0016	5494265	Spokane River (River Mile 77.0)	Upriver Dam to Nine Mile Dam	Mountain whitefish	Salmon Group	Fillet/Skin-on	9/29/2005	2005	S		220	ppb_{ww}		9	Yes	TotPCBar	47.676551	-117.382298
DSER0016	5494266	Spokane River (River Mile 77.0)	Upriver Dam to Nine Mile Dam	Mountain whitefish	Salmon Group	Fillet/Skin-on	9/29/2005	2005	S		203	ppb_{ww}		9	Yes	TotPCBar	47.676551	-117.382298
DSER0016	5494267	Spokane River (River Mile 64.0)	Upriver Dam to Nine Mile Dam	Mountain whitefish	Salmon Group	Fillet/Skin-on	9/29/2005	2005	S		160	ppb_{ww}		9	Yes	TotPCBar	47.720434	-117.500603
DSER0016	5494268	Spokane River (River Mile 64.0)	Upriver Dam to Nine Mile Dam	Mountain whitefish	Salmon Group	Fillet/Skin-on	9/29/2005	2005	S		86	ppb_{ww}		9	Yes	TotPCBar	47.720434	-117.500603
DSER0016	5494269	Spokane River (River Mile 64.0)	Upriver Dam to Nine Mile Dam	Rainbow trout	Trout Group	Fillet/Skin-on	9/29/2005	2005	S		45.7	ppb_{ww}		9	Yes	TotPCBar	47.720434	-117.500603
DSER0016	5494270	Spokane River (River Mile 64.0)	Upriver Dam to Nine Mile Dam	Rainbow trout	Trout Group	Fillet/Skin-on	9/29/2005	2005	S		78	ppb_{ww}		9	Yes	TotPCBar	47.720434	-117.500603
DSER0016	5494271	Spokane River (River Mile 64.0)	Upriver Dam to Nine Mile Dam	Mountain whitefish	Salmon Group	Fillet/Skin-on	9/29/2005	2005	S		172	ppb_{ww}		9	Yes	TotPCBar	47.720434	-117.500603
DSER0016	5494272	Spokane River (River Mile 64.0)	Upriver Dam to Nine Mile Dam	Rainbow trout	Trout Group	Fillet/Skin-on	9/29/2005	2005	S		94	ppb_{ww}		9	Yes	TotPCBar	47.720434	-117.500603

Table B-4c. Total PCBs Concentrations in PRA Gamefish Collected from the Spokane River and Lake Roosevelt

Study ID	Sample ID	Location ID	Reach	Fish Species Common Name	PRA Gamefish Group	Tissue Type	Date Collected	Year Collected	Sample Type	Parent Sample	Conc	Units	Flag	Aroclor or Congener Count	Detected	PCB Type	Location Latitude	Location Longitude
DSER0016	5494273	Spokane River (River Mile 40.8)	Nine Mile Dam to Long Lake Dam	Smallmouth bass	Bass Group	Fillet/Skin-on	11/3/2005	2005	S		49	ppb_{ww}		9	Yes	TotPCBar	47.841521	-117.724988
DSER0016	5494274	Spokane River (River Mile 40.8)	Nine Mile Dam to Long Lake Dam	Smallmouth bass	Bass Group	Fillet/Skin-on	11/3/2005	2005	S		82	ppb_{ww}		9	Yes	TotPCBar	47.841521	-117.724988
DSER0016	5494275	Spokane River (River Mile 40.8)	Nine Mile Dam to Long Lake Dam	Smallmouth bass	Bass Group	Fillet/Skin-on	11/3/2005	2005	S		71.2	ppb_{ww}		9	Yes	TotPCBar	47.841521	-117.724988
DSER0016	5494276	Spokane River (River Mile 55.2)	Nine Mile Dam to Long Lake Dam	Brown trout	Trout Group	Fillet/Skin-on	11/3/2005	2005	S		130	ppb_{ww}		9	Yes	TotPCBar	47.801558	-117.557685
DSER0016	5494277	Spokane River (River Mile 55.6)	Nine Mile Dam to Long Lake Dam	Smallmouth bass	Bass Group	Fillet/Skin-on	9/27/2005	2005	S		36.9	ppb_{ww}		9	Yes	TotPCBar	47.80089	-117.548598
EPALR05B	RH6F15	COLUMBIA RIVER - FOCUS AREA 6	Lake Roosevelt	Rainbow trout	Trout Group	Fillet/Skin-on	10/21/2005	2005	S		6.7	ppb_{ww}		9	Yes	TotPCBar	47.934104	-118.8261533
EPALR05B	RH6F25	COLUMBIA RIVER - FOCUS AREA 6	Lake Roosevelt	Rainbow trout	Trout Group	Fillet/Skin-on	10/21/2005	2005	S		9.4	ppb_{ww}		9	Yes	TotPCBar	47.934104	-118.8261533
EPALR05B	RH6F35	COLUMBIA RIVER - FOCUS AREA 6	Lake Roosevelt	Rainbow trout	Trout Group	Fillet/Skin-on	10/21/2005	2005	S		8.54	ppb_{ww}		166	Yes	TotPCBcong	47.934104	-118.8261533
EPALR05B	RH6F35	COLUMBIA RIVER - FOCUS AREA 6	Lake Roosevelt	Rainbow trout	Trout Group	Fillet/Skin-on	10/21/2005	2005	S		10.8	ppb_{ww}		9	Yes	TotPCBar	47.934104	-118.8261533
EPALR05B	RH6F45	COLUMBIA RIVER - FOCUS AREA 6	Lake Roosevelt	Rainbow trout	Trout Group	Fillet/Skin-on	10/21/2005	2005	S		5.7	ppb_{ww}		9	Yes	TotPCBar	47.934104	-118.8261533
EPALR05B	RW6F14	COLUMBIA RIVER - FOCUS AREA 6	Lake Roosevelt	Rainbow trout	Trout Group	Fillet/Skin-on	10/21/2005	2005	S		5.7	ppb_{ww}		8	Yes	TotPCBar	47.934104	-118.8261533
EPALR05B	WE6F15	COLUMBIA RIVER - FOCUS AREA 6	Lake Roosevelt	Walleye	Walleye Group	Fillet/Skin-on	9/14/2005	2005	S		1.7	ppb_{ww}		8	Yes	TotPCBar	47.934104	-118.8261533
EPALR05B	WE6F25	COLUMBIA RIVER - FOCUS AREA 6	Lake Roosevelt	Walleye	Walleye Group	Fillet/Skin-on	9/14/2005	2005	S		3.7	ppb_{ww}		8	Yes	TotPCBar	47.934104	-118.8261533
EPALR05B	WE6F35	COLUMBIA RIVER - FOCUS AREA 6	Lake Roosevelt	Walleye	Walleye Group	Fillet/Skin-on	9/14/2005	2005	S		4.2	ppb_{ww}		8	Yes	TotPCBar	47.934104	-118.8261533
EPALR05B	WE6F35	COLUMBIA RIVER - FOCUS AREA 6	Lake Roosevelt	Walleye	Walleye Group	Fillet/Skin-on	9/14/2005	2005	S		6	ppb_{ww}		166	Yes	TotPCBcong	47.934104	-118.8261533
EPALR05B	WE6F45	COLUMBIA RIVER - FOCUS AREA 6	Lake Roosevelt	Walleye	Walleye Group	Fillet/Skin-on	9/14/2005	2005	S		4.5	ppb_{ww}		8	Yes	TotPCBar	47.934104	-118.8261533
EPALR05B	WE6F55	COLUMBIA RIVER - FOCUS AREA 6	Lake Roosevelt	Walleye	Walleye Group	Fillet/Skin-on	9/14/2005	2005	S		3.3	ppb_{ww}		8	Yes	TotPCBar	47.934104	-118.8261533
RJAC002	2138291	ULL	Nine Mile Dam to Long Lake Dam	Smallmouth bass	Bass Group	Fillet/Skin-on	6/18/2001	2001	S		32.4	ppb_{ww}		7	Yes	TotPCBar	47.796617	-117.5857974
RJAC002	2138292	ULL	Nine Mile Dam to Long Lake Dam	Smallmouth bass	Bass Group	Fillet/Skin-on	6/18/2001	2001	S		39.5	ppb_{ww}		7	Yes	TotPCBar	47.796617	-117.5857974
RJAC002	2138293	ULL	Nine Mile Dam to Long Lake Dam	Smallmouth bass	Bass Group	Fillet/Skin-on	6/18/2001	2001	S		54	ppb_{ww}		7	Yes	TotPCBar	47.796617	-117.5857974
RJAC002	2138294	LLL	Nine Mile Dam to Long Lake Dam	Smallmouth bass	Bass Group	Fillet/Skin-on	6/18/2001	2001	S		33	ppb_{ww}		7	Yes	TotPCBar	47.809382	-117.7961889
RJAC002	2138295	LLL	Nine Mile Dam to Long Lake Dam	Smallmouth bass	Bass Group	Fillet/Skin-on	6/18/2001	2001	S		11	ppb_{ww}	U	7	No	TotPCBar	47.809382	-117.7961889
RJAC002	2138296	LLL	Nine Mile Dam to Long Lake Dam	Smallmouth bass	Bass Group	Fillet/Skin-on	6/18/2001	2001	S		31	ppb_{ww}		7	Yes	TotPCBar	47.809382	-117.7961889
RJAC002	2138297	LLL	Nine Mile Dam to Long Lake Dam	Yellow perch	Perch Group	Fillet/Skin-on	6/18/2001	2001	S		10	ppb_{ww}	U	7	No	TotPCBar	47.809382	-117.7961889
RJAC002	2148298	LLL	Nine Mile Dam to Long Lake Dam	Yellow perch	Perch Group	Fillet/Skin-on	6/18/2001	2001	S		11	ppb_{ww}	U	7	No	TotPCBar	47.809382	-117.7961889
RJAC002	2148299	LLL	Nine Mile Dam to Long Lake Dam	Yellow perch	Perch Group	Fillet/Skin-on	6/18/2001	2001	S		10	ppb_{ww}	U	7	No	TotPCBar	47.809382	-117.7961889

Table B-4c. Total PCBs Concentrations in PRA Gamefish Collected from the Spokane River and Lake Roosevelt

Study ID	Sample ID	Location ID	Reach	Fish Species Common Name	PRA Gamefish Group	Tissue Type	Date Collected	Year Collected	Sample Type	Parent Sample	Conc	Units	Flag	Aroclor or Congener Count	Detected	PCB Type	Location Latitude	Location Longitude
RJAC002	2148300	ULL	Nine Mile Dam to Long Lake Dam	Yellow perch	Perch Group	Fillet/Skin-on	6/18/2001	2001	S		11	ppb_{ww}	U	7	No	TotPCBar	47.796617	-117.5857974
RJAC002	2148301	ULL	Nine Mile Dam to Long Lake Dam	Yellow perch	Perch Group	Fillet/Skin-on	6/18/2001	2001	S		11	ppb_{ww}	U	7	No	TotPCBar	47.796617	-117.5857974
RJAC002	2148302	ULL	Nine Mile Dam to Long Lake Dam	Yellow perch	Perch Group	Fillet/Skin-on	6/18/2001	2001	S		11	ppb_{ww}	U	7	No	TotPCBar	47.796617	-117.5857974
RJAC002	2158303	LLL	Nine Mile Dam to Long Lake Dam	Largemouth bass	Bass Group	Fillet/Skin-on	6/18/2001	2001	S		47	ppb_{ww}		7	Yes	TotPCBar	47.809382	-117.7961889
RJAC002	2158303	LLL	Nine Mile Dam to Long Lake Dam	Largemouth bass	Bass Group	Fillet/Skin-on	6/19/2001	2001	S		70	ppb_{ww}		158	Yes	TotPCBcong	47.809382	-117.7961889
RJAC002	2158304	LLL	Nine Mile Dam to Long Lake Dam	Largemouth bass	Bass Group	Fillet/Skin-on	6/18/2001	2001	S		64	ppb_{ww}		7	Yes	TotPCBar	47.809382	-117.7961889
RJAC002	2158304	LLL	Nine Mile Dam to Long Lake Dam	Largemouth bass	Bass Group	Fillet/Skin-on	6/19/2001	2001	S		65	ppb_{ww}		158	Yes	TotPCBcong	47.809382	-117.7961889
RJAC002	2158305	LLL	Nine Mile Dam to Long Lake Dam	Largemouth bass	Bass Group	Fillet/Skin-on	6/18/2001	2001	S		57	ppb_{ww}		7	Yes	TotPCBar	47.809382	-117.7961889
RJAC002	2158305	LLL	Nine Mile Dam to Long Lake Dam	Largemouth bass	Bass Group	Fillet/Skin-on	6/19/2001	2001	S		101	ppb_{ww}		158	Yes	TotPCBcong	47.809382	-117.7961889
RJAC002	2158306	ULL	Nine Mile Dam to Long Lake Dam	Largemouth bass	Bass Group	Fillet/Skin-on	6/18/2001	2001	S		39.2	ppb_{ww}		7	Yes	TotPCBar	47.796617	-117.5857974
RJAC002	2158306	ULL	Nine Mile Dam to Long Lake Dam	Largemouth bass	Bass Group	Fillet/Skin-on	6/19/2001	2001	S		43.5	ppb_{ww}		158	Yes	TotPCBcong	47.796617	-117.5857974
RJAC002	2158307	ULL	Nine Mile Dam to Long Lake Dam	Largemouth bass	Bass Group	Fillet/Skin-on	6/18/2001	2001	S		72	ppb_{ww}		7	Yes	TotPCBar	47.796617	-117.5857974
RJAC002	2158307	ULL	Nine Mile Dam to Long Lake Dam	Largemouth bass	Bass Group	Fillet/Skin-on	6/19/2001	2001	S		89.9	ppb_{ww}		158	Yes	TotPCBcong	47.796617	-117.5857974
RJAC002	2158308	ULL	Nine Mile Dam to Long Lake Dam	Mountain whitefish	Salmon Group	Fillet/Skin-on	6/18/2001	2001	S		89	ppb_{ww}		7	Yes	TotPCBar	47.796617	-117.5857974
RJAC002	2158308	ULL	Nine Mile Dam to Long Lake Dam	Mountain whitefish	Salmon Group	Fillet/Skin-on	6/19/2001	2001	S		85.1	ppb_{ww}		158	Yes	TotPCBcong	47.796617	-117.5857974
RJAC002	2158309	ULL	Nine Mile Dam to Long Lake Dam	Mountain whitefish	Salmon Group	Fillet/Skin-on	6/18/2001	2001	S		60	ppb_{ww}		7	Yes	TotPCBar	47.796617	-117.5857974
RJAC002	2158309	ULL	Nine Mile Dam to Long Lake Dam	Mountain whitefish	Salmon Group	Fillet/Skin-on	6/19/2001	2001	S		68.3	ppb_{ww}		158	Yes	TotPCBcong	47.796617	-117.5857974
RJAC002	2158310	ULL	Nine Mile Dam to Long Lake Dam	Mountain whitefish	Salmon Group	Fillet/Skin-on	6/18/2001	2001	S		70	ppb_{ww}		7	Yes	TotPCBar	47.796617	-117.5857974
RJAC002	2158310	ULL	Nine Mile Dam to Long Lake Dam	Mountain whitefish	Salmon Group	Fillet/Skin-on	6/19/2001	2001	S		80.9	ppb_{ww}		158	Yes	TotPCBcong	47.796617	-117.5857974
RJAC002	2158311	ULL	Nine Mile Dam to Long Lake Dam	Largemouth bass	Bass Group	Fillet/Skin-on	6/18/2001	2001	S		38.8	ppb_{ww}		7	Yes	TotPCBar	47.796617	-117.5857974
RJAC002	2158311	ULL	Nine Mile Dam to Long Lake Dam	Largemouth bass	Bass Group	Fillet/Skin-on	6/19/2001	2001	S		40.3	ppb_{ww}		158	Yes	TotPCBcong	47.796617	-117.5857974
WSTMP03T	3084281	Spokane-F	Upriver Dam to Nine Mile Dam	Rainbow trout	Trout Group	Fillet/Skin-on	9/16/2003	2003	S		9.7	ppb_{ww}		163	Yes	TotPCBcong	47.7324	-117.5096
WSTMP03T	3084282	Spokane-F	Upriver Dam to Nine Mile Dam	Rainbow trout	Trout Group	Fillet/Skin-on	9/16/2003	2003	S		52.8	ppb_{ww}		163	Yes	TotPCBcong	47.7324	-117.5096
WSTMP03T	3084283	Spokane-F	Upriver Dam to Nine Mile Dam	Rainbow trout	Trout Group	Fillet/Skin-on	9/16/2003	2003	S		13.5	ppb_{ww}		163	Yes	TotPCBcong	47.7324	-117.5096
WSTMP03T	3084284	Spokane-F	Upriver Dam to Nine Mile Dam	Rainbow trout	Trout Group	Fillet/Skin-on	9/16/2003	2003	S		34.4	ppb_{ww}		163	Yes	TotPCBcong	47.7324	-117.5096
WSTMP03T	3084285	Spokane-F	Upriver Dam to Nine Mile Dam	Rainbow trout	Trout Group	Fillet/Skin-on	9/16/2003	2003	S		50.9	ppb_{ww}		163	Yes	TotPCBcong	47.7324	-117.5096

Table B-4c. Total PCBs Concentrations in PRA Gamefish Collected from the Spokane River and Lake Roosevelt

Study ID	Sample ID	Location ID	Reach	Fish Species Common Name	PRA Gamefish Group	Tissue Type	Date Collected	Year Collected	Sample Type	Parent Sample	Conc	Units	Flag	Aroclor or Congener Count	Detected	PCB Type	Location Latitude	Location Longitude
WSTMP03T	3084286	Spokane-F	Upriver Dam to Nine Mile Dam	Rainbow trout	Trout Group	Fillet/Skin-on	9/16/2003	2003	S		11.6	ppb_{ww}		163	Yes	TotPCBcong	47.7324	-117.5096
WSTMP03T	3084287	Spokane-F	Upriver Dam to Nine Mile Dam	Rainbow trout	Trout Group	Fillet/Skin-on	9/16/2003	2003	S		12.3	ppb_{ww}		163	Yes	TotPCBcong	47.7324	-117.5096
WSTMP03T	3084288	Spokane-F	Upriver Dam to Nine Mile Dam	Rainbow trout	Trout Group	Fillet/Skin-on	9/16/2003	2003	S		17.3	ppb_{ww}		163	Yes	TotPCBcong	47.7324	-117.5096
WSTMP03T	3084289	Spokane-F	Upriver Dam to Nine Mile Dam	Rainbow trout	Trout Group	Fillet/Skin-on	9/16/2003	2003	S		42.4	ppb_{ww}		163	Yes	TotPCBcong	47.7324	-117.5096
WSTMP03T	3084290	Spokane-F	Upriver Dam to Nine Mile Dam	Rainbow trout	Trout Group	Fillet/Skin-on	9/16/2003	2003	S		74.5	ppb_{ww}		163	Yes	TotPCBcong	47.7324	-117.5096
WSTMP03T	3084291	Spokane-F	Upriver Dam to Nine Mile Dam	Rainbow trout	Trout Group	Fillet/Skin-on	9/16/2003	2003	S		51.9	ppb_{ww}		163	Yes	TotPCBcong	47.7324	-117.5096
WSTMP03T	3084292	Spokane-F	Upriver Dam to Nine Mile Dam	Rainbow trout	Trout Group	Fillet/Skin-on	9/16/2003	2003	S		44.8	ppb_{ww}		163	Yes	TotPCBcong	47.7324	-117.5096
WSTMP03T	3084293	Spokane-F	Upriver Dam to Nine Mile Dam	Rainbow trout	Trout Group	Fillet/Skin-on	9/16/2003	2003	S		27.1	ppb_{ww}		163	Yes	TotPCBcong	47.7324	-117.5096
WSTMP03T	3084294	Spokane-F	Upriver Dam to Nine Mile Dam	Rainbow trout	Trout Group	Fillet/Skin-on	9/16/2003	2003	S		9.7	ppb_{ww}		163	Yes	TotPCBcong	47.7324	-117.5096
WSTMP03T	3084295	Spokane-F	Upriver Dam to Nine Mile Dam	Rainbow trout	Trout Group	Fillet/Skin-on	9/16/2003	2003	S		14.6	ppb_{ww}		163	Yes	TotPCBcong	47.7324	-117.5096
WSTMP03T	3084296	Spokane-F	Upriver Dam to Nine Mile Dam	Rainbow trout	Trout Group	Fillet/Skin-on	9/16/2003	2003	S		10.7	ppb_{ww}		163	Yes	TotPCBcong	47.7324	-117.5096
WSTMP03T	3084298	Spokane-F	Upriver Dam to Nine Mile Dam	Rainbow trout	Trout Group	Fillet/Skin-on	9/16/2003	2003	S		15.6	ppb_{ww}		163	Yes	TotPCBcong	47.7324	-117.5096
WSTMP03T	3084299	Spokane-F	Upriver Dam to Nine Mile Dam	Rainbow trout	Trout Group	Fillet/Skin-on	9/16/2003	2003	S		16.8	ppb_{ww}		163	Yes	TotPCBcong	47.7324	-117.5096
WSTMP03T	3084301	Spokane-F	Upriver Dam to Nine Mile Dam	Rainbow trout	Trout Group	Fillet/Skin-on	9/16/2003	2003	S		43.1	ppb_{ww}		163	Yes	TotPCBcong	47.7324	-117.5096
WSTMP03T	3084302	Spokane-F	Upriver Dam to Nine Mile Dam	Rainbow trout	Trout Group	Fillet/Skin-on	9/16/2003	2003	S		20.1	ppb_{ww}		163	Yes	TotPCBcong	47.7324	-117.5096
WSTMP03T	3084303	Spokane-F	Upriver Dam to Nine Mile Dam	Rainbow trout	Trout Group	Fillet/Skin-on	9/16/2003	2003	S		28.7	ppb_{ww}		163	Yes	TotPCBcong	47.7324	-117.5096
WSTMP03T	3084304	Spokane-F	Upriver Dam to Nine Mile Dam	Rainbow trout	Trout Group	Fillet/Skin-on	9/16/2003	2003	S		10.4	ppb_{ww}		163	Yes	TotPCBcong	47.7324	-117.5096
WSTMP03T	3084305	Spokane-F	Upriver Dam to Nine Mile Dam	Rainbow trout	Trout Group	Fillet/Skin-on	9/16/2003	2003	S		12.1	ppb_{ww}		163	Yes	TotPCBcong	47.7324	-117.5096
WSTMP03T	3084306	Spokane-F	Upriver Dam to Nine Mile Dam	Rainbow trout	Trout Group	Fillet/Skin-on	9/16/2003	2003	S		34.6	ppb_{ww}		163	Yes	TotPCBcong	47.7324	-117.5096
WSTMP03T	3084308	Spokane-F	Upriver Dam to Nine Mile Dam	Rainbow trout	Trout Group	Fillet/Skin-on	9/16/2003	2003	FD	3084282	59.1	ppb_{ww}		163	Yes	TotPCBcong	47.7324	-117.5096
WSTMP12	1301011-56	SPK 77.0	Upriver Dam to Nine Mile Dam	Mountain whitefish	Salmon Group	Fillet/Skin-on	9/19/2012	2012	S		130	ppb_{ww}		162	Yes	TotPCBcong	47.676551	-117.382298
WSTMP12	1301011-56	SPK 77.0	Upriver Dam to Nine Mile Dam	Mountain whitefish	Salmon Group	Fillet/Skin-on	9/19/2012	2012	S		130	ppb_{ww}		9	Yes	TotPCBar	47.676551	-117.382298
WSTMP12	1301011-57	SPK 77.0	Upriver Dam to Nine Mile Dam	Mountain whitefish	Salmon Group	Fillet/Skin-on	9/19/2012	2012	S		46	ppb_{ww}		9	Yes	TotPCBar	47.676551	-117.382298
WSTMP12	1301011-57	SPK 77.0	Upriver Dam to Nine Mile Dam	Mountain whitefish	Salmon Group	Fillet/Skin-on	9/19/2012	2012	S		53.9	ppb_{ww}		162	Yes	TotPCBcong	47.676551	-117.382298
WSTMP12	1301011-58	SPK 77.0	Upriver Dam to Nine Mile Dam	Mountain whitefish	Salmon Group	Fillet/Skin-on	9/19/2012	2012	S		161	ppb_{ww}		162	Yes	TotPCBcong	47.676551	-117.382298
WSTMP12	1301011-58	SPK 77.0	Upriver Dam to Nine Mile Dam	Mountain whitefish	Salmon Group	Fillet/Skin-on	9/19/2012	2012	S		170	ppb_{ww}		9	Yes	TotPCBar	47.676551	-117.382298

Table B-4c. Total PCBs Concentrations in PRA Gamefish Collected from the Spokane River and Lake Roosevelt

Study ID	Sample ID	Location ID	Reach	Fish Species Common Name	PRA Gamefish Group	Tissue Type	Date Collected	Year Collected	Sample Type	Parent Sample	Conc	Units	Flag	Aroclor or Congener Count	Detected	PCB Type	Location Latitude	Location Longitude
WSTMP12	1301011-59	SPK 77.0	Upriver Dam to Nine Mile Dam	Mountain whitefish	Salmon Group	Fillet/Skin-on	9/19/2012	2012	S		124	ppb$_{ww}$		9	Yes	TotPCBar	47.676551	-117.382298
WSTMP12	1301011-60	SPK 77.0	Upriver Dam to Nine Mile Dam	Mountain whitefish	Salmon Group	Fillet/Skin-on	9/19/2012	2012	S		129	ppb$_{ww}$		162	Yes	TotPCBcong	47.676551	-117.382298
WSTMP12	1301011-60	SPK 77.0	Upriver Dam to Nine Mile Dam	Mountain whitefish	Salmon Group	Fillet/Skin-on	9/19/2012	2012	S		158	ppb$_{ww}$		9	Yes	TotPCBar	47.676551	-117.382298
WSTMP12	1301011-61	SPK 64.0	Upriver Dam to Nine Mile Dam	Mountain whitefish	Salmon Group	Fillet/Skin-on	9/25/2012	2012	S		122	ppb$_{ww}$		9	Yes	TotPCBar	47.720434	-117.500603
WSTMP12	1301011-61	SPK 64.0	Upriver Dam to Nine Mile Dam	Mountain whitefish	Salmon Group	Fillet/Skin-on	9/25/2012	2012	S		157	ppb$_{ww}$		162	Yes	TotPCBcong	47.720434	-117.500603
WSTMP12	1301011-62	SPK 64.0	Upriver Dam to Nine Mile Dam	Mountain whitefish	Salmon Group	Fillet/Skin-on	9/25/2012	2012	S		168	ppb$_{ww}$		162	Yes	TotPCBcong	47.720434	-117.500603
WSTMP12	1301011-62	SPK 64.0	Upriver Dam to Nine Mile Dam	Mountain whitefish	Salmon Group	Fillet/Skin-on	9/25/2012	2012	S		192	ppb$_{ww}$		9	Yes	TotPCBar	47.720434	-117.500603
WSTMP12	1301011-63	SPK 64.0	Upriver Dam to Nine Mile Dam	Mountain whitefish	Salmon Group	Fillet/Skin-on	9/25/2012	2012	S		185	ppb$_{ww}$		9	Yes	TotPCBar	47.720434	-117.500603
WSTMP12	1301011-64	SPK 64.0	Upriver Dam to Nine Mile Dam	Mountain whitefish	Salmon Group	Fillet/Skin-on	9/25/2012	2012	S		157	ppb$_{ww}$		9	Yes	TotPCBar	47.720434	-117.500603
WSTMP12	1301011-65	SPK 64.0	Upriver Dam to Nine Mile Dam	Mountain whitefish	Salmon Group	Fillet/Skin-on	9/25/2012	2012	S		183	ppb$_{ww}$		9	Yes	TotPCBar	47.720434	-117.500603
WSTMP12	1301011-66	SPK 64.0	Upriver Dam to Nine Mile Dam	Mountain whitefish	Salmon Group	Fillet/Skin-on	9/25/2012	2012	S		143	ppb$_{ww}$		9	Yes	TotPCBar	47.720434	-117.500603
WSTMP12	1301011-67	SPK 64.0	Upriver Dam to Nine Mile Dam	Mountain whitefish	Salmon Group	Fillet/Skin-on	9/25/2012	2012	S		152	ppb$_{ww}$		9	Yes	TotPCBar	47.720434	-117.500603
WSTMP12	1301011-68	SPK 56.5	Nine Mile Dam to Long Lake Dam	Mountain whitefish	Salmon Group	Fillet/Skin-on	9/26/2012	2012	S		97	ppb$_{ww}$		9	Yes	TotPCBar	47.79274	-117.53435
WSTMP12	1301011-68	SPK 56.5	Nine Mile Dam to Long Lake Dam	Mountain whitefish	Salmon Group	Fillet/Skin-on	9/26/2012	2012	S		115	ppb$_{ww}$		162	Yes	TotPCBcong	47.79274	-117.53435
WSTMP12	1301011-69	SPK 56.5	Nine Mile Dam to Long Lake Dam	Mountain whitefish	Salmon Group	Fillet/Skin-on	9/26/2012	2012	S		211	ppb$_{ww}$		9	Yes	TotPCBar	47.79274	-117.53435
WSTMP12	1301011-69	SPK 56.5	Nine Mile Dam to Long Lake Dam	Mountain whitefish	Salmon Group	Fillet/Skin-on	9/26/2012	2012	S		213	ppb$_{ww}$		162	Yes	TotPCBcong	47.79274	-117.53435
WSTMP12	1301011-70	SPK 56.5	Nine Mile Dam to Long Lake Dam	Mountain whitefish	Salmon Group	Fillet/Skin-on	9/26/2012	2012	S		22	ppb$_{ww}$		9	Yes	TotPCBar	47.79274	-117.53435
WSTMP12	1301011-70	SPK 56.5	Nine Mile Dam to Long Lake Dam	Mountain whitefish	Salmon Group	Fillet/Skin-on	9/26/2012	2012	S		49.3	ppb$_{ww}$		162	Yes	TotPCBcong	47.79274	-117.53435
WSTMP12	1301011-71	SPK 56.5	Nine Mile Dam to Long Lake Dam	Mountain whitefish	Salmon Group	Fillet/Skin-on	9/26/2012	2012	S		50	ppb$_{ww}$		9	Yes	TotPCBar	47.79274	-117.53435
WSTMP12	1301011-72	SPK 56.5	Nine Mile Dam to Long Lake Dam	Mountain whitefish	Salmon Group	Fillet/Skin-on	9/26/2012	2012	S		158	ppb$_{ww}$		9	Yes	TotPCBar	47.79274	-117.53435
WSTMP12	1301011-73	SPK 56.5	Nine Mile Dam to Long Lake Dam	Mountain whitefish	Salmon Group	Fillet/Skin-on	9/26/2012	2012	S		81	ppb$_{ww}$		9	Yes	TotPCBar	47.79274	-117.53435
WSTMP12	1301011-74	SPK 56.5	Nine Mile Dam to Long Lake Dam	Mountain whitefish	Salmon Group	Fillet/Skin-on	9/26/2012	2012	S		91	ppb$_{ww}$		9	Yes	TotPCBar	47.79274	-117.53435
WSTMP12	1301011-80	SPK 77.0	Upriver Dam to Nine Mile Dam	Rainbow trout	Trout Group	Fillet/Skin-on	9/19/2012	2012	S		41	ppb$_{ww}$		9	Yes	TotPCBar	47.676551	-117.382298
WSTMP12	1301011-80	SPK 77.0	Upriver Dam to Nine Mile Dam	Rainbow trout	Trout Group	Fillet/Skin-on	9/19/2012	2012	S		54.5	ppb$_{ww}$		162	Yes	TotPCBcong	47.676551	-117.382298
WSTMP12	1301011-81	SPK 77.0	Upriver Dam to Nine Mile Dam	Rainbow trout	Trout Group	Fillet/Skin-on	9/19/2012	2012	S		65	ppb$_{ww}$		9	Yes	TotPCBar	47.676551	-117.382298
WSTMP12	1301011-81	SPK 77.0	Upriver Dam to Nine Mile Dam	Rainbow trout	Trout Group	Fillet/Skin-on	9/19/2012	2012	S		93.6	ppb$_{ww}$		162	Yes	TotPCBcong	47.676551	-117.382298

Table B-4c. Total PCBs Concentrations in PRA Gamefish Collected from the Spokane River and Lake Roosevelt

Study ID	Sample ID	Location ID	Reach	Fish Species Common Name	PRA Gamefish Group	Tissue Type	Date Collected	Year Collected	Sample Type	Parent Sample	Conc	Units	Flag	Aroclor or Congener Count	Detected	PCB Type	Location Latitude	Location Longitude
WSTMP12	1301011-82	SPK 77.0	Upriver Dam to Nine Mile Dam	Rainbow trout	Trout Group	Fillet/Skin-on	9/19/2012	2012	S		100	ppb_{ww}		9	Yes	TotPCBar	47.676551	-117.382298
WSTMP12	1301011-82	SPK 77.0	Upriver Dam to Nine Mile Dam	Rainbow trout	Trout Group	Fillet/Skin-on	9/19/2012	2012	S		152	ppb_{ww}		162	Yes	TotPCBcong	47.676551	-117.382298
WSTMP12	1301011-83	SPK 64.0	Upriver Dam to Nine Mile Dam	Rainbow trout	Trout Group	Fillet/Skin-on	9/25/2012	2012	S		42.2	ppb_{ww}		162	Yes	TotPCBcong	47.720434	-117.500603
WSTMP12	1301011-83	SPK 64.0	Upriver Dam to Nine Mile Dam	Rainbow trout	Trout Group	Fillet/Skin-on	9/25/2012	2012	S		49	ppb_{ww}		9	Yes	TotPCBar	47.720434	-117.500603
WSTMP12	1301011-84	SPK 64.0	Upriver Dam to Nine Mile Dam	Rainbow trout	Trout Group	Fillet/Skin-on	9/25/2012	2012	S		49	ppb_{ww}		9	Yes	TotPCBar	47.720434	-117.500603
WSTMP12	1301011-84	SPK 64.0	Upriver Dam to Nine Mile Dam	Rainbow trout	Trout Group	Fillet/Skin-on	9/25/2012	2012	S		52.1	ppb_{ww}		162	Yes	TotPCBcong	47.720434	-117.500603
WSTMP12	1301011-85	SPK 64.0	Upriver Dam to Nine Mile Dam	Rainbow trout	Trout Group	Fillet/Skin-on	9/25/2012	2012	S		33	ppb_{ww}		9	Yes	TotPCBar	47.720434	-117.500603
WSTMP12	1301011-85	SPK 64.0	Upriver Dam to Nine Mile Dam	Rainbow trout	Trout Group	Fillet/Skin-on	9/25/2012	2012	S		34.4	ppb_{ww}		162	Yes	TotPCBcong	47.720434	-117.500603
WSTMP12	1301011-86	SPK84.4	Post Falls Dam to Upriver Dam	Rainbow trout	Trout Group	Fillet/Skin-on	9/20/2012	2012	S		38	ppb_{ww}		9	Yes	TotPCBar	47.694463	-117.2483067
WSTMP12	1301011-86	SPK84.4	Post Falls Dam to Upriver Dam	Rainbow trout	Trout Group	Fillet/Skin-on	9/20/2012	2012	S		41.5	ppb_{ww}		162	Yes	TotPCBcong	47.694463	-117.2483067
WSTMP12	1301011-87	SPK84.4	Post Falls Dam to Upriver Dam	Rainbow trout	Trout Group	Fillet/Skin-on	9/20/2012	2012	S		9.9	ppb_{ww}	U	9	No	TotPCBar	47.694463	-117.2483067
WSTMP12	1301011-87	SPK84.4	Post Falls Dam to Upriver Dam	Rainbow trout	Trout Group	Fillet/Skin-on	9/20/2012	2012	S		25.4	ppb_{ww}		162	Yes	TotPCBcong	47.694463	-117.2483067
WSTMP12	1301011-88	SPK84.4	Post Falls Dam to Upriver Dam	Rainbow trout	Trout Group	Fillet/Skin-on	9/20/2012	2012	S		29.9	ppb_{ww}		162	Yes	TotPCBcong	47.694463	-117.2483067
WSTMP12	1301011-88	SPK84.4	Post Falls Dam to Upriver Dam	Rainbow trout	Trout Group	Fillet/Skin-on	9/20/2012	2012	S		38	ppb_{ww}		9	Yes	TotPCBar	47.694463	-117.2483067
WSTMP12	1301011-89	SPK 56.5	Nine Mile Dam to Long Lake Dam	Rainbow trout	Trout Group	Fillet/Skin-on	9/26/2012	2012	S		37	ppb_{ww}		9	Yes	TotPCBar	47.79274	-117.53435
WSTMP12	1301011-90	Spokane Arm of FDR Rsvr, RM 27-29	Long Lake Dam to Lake Roosevelt	Brown trout	Trout Group	Fillet/Skin-on	11/5/2012	2012	S		39	ppb_{ww}		9	Yes	TotPCBar	47.82554	-117.94177
WSTMP12	1301011-91	Spokane Arm of FDR Rsvr, RM 27-29	Long Lake Dam to Lake Roosevelt	Rainbow trout	Trout Group	Fillet/Skin-on	11/5/2012	2012	S		15.4	ppb_{ww}		9	Yes	TotPCBar	47.82554	-117.94177
WSTMP12	1301011-92	Spokane Arm of FDR Rsvr, RM 27-29	Long Lake Dam to Lake Roosevelt	Rainbow trout	Trout Group	Fillet/Skin-on	11/5/2012	2012	S		9.7	ppb_{ww}	U	9	No	TotPCBar	47.82554	-117.94177
WSTMP12	1301011-93	Spokane Arm of FDR Rsvr, RM 27-29	Long Lake Dam to Lake Roosevelt	Rainbow trout	Trout Group	Fillet/Skin-on	11/5/2012	2012	S		9.7	ppb_{ww}	U	9	No	TotPCBar	47.82554	-117.94177
WSTMP12	1301011-94	Spokane Arm of FDR Rsvr, RM 27-29	Long Lake Dam to Lake Roosevelt	Rainbow trout	Trout Group	Fillet/Skin-on	11/5/2012	2012	S		59	ppb_{ww}		9	Yes	TotPCBar	47.82554	-117.94177
WSTMP12	1301011-95	Spokane Arm of FDR Rsvr, RM 27-29	Long Lake Dam to Lake Roosevelt	Rainbow trout	Trout Group	Fillet/Skin-on	11/5/2012	2012	S		9.7	ppb_{ww}	U	9	No	TotPCBar	47.82554	-117.94177

Notes:

PCB Types: TotPCBar = sum of detected Aroclor PCBs; TotPCBcong = sum of detected PCB congeners

PCB = polychlorinated biphenyl

ppb_{ww} = parts per billion wet weight

PRA = probabalistic risk assessment

Table B-4d. Summary of Total PCBs Concentrations by PRA Gamefish Collected from the Spokane River and Lake Roosevelt

			Summary Statistics				ProUCL Output				
River Area	PRA Gamefish Groups	Years Collected	Frequency of Detection	Half-DL Arithmetic Mean	Range of Positive Results	Range of Detection Limits for Non-Detect Results	Distribution Type	KM Mean[a]	Mean Type	95UCL[b]	Basis for 95UCL Recommended by ProUCL
Spokane River (River-wide) plus Lake Roosevelt	All Gamefish	2001, 2003, 2005, 2012	111/122	64.3	1.7 to 280	9.6 to 11	Gamma	64.4	KM Mean	76.2	95% GROS Approximate Gamma UCL
	Bass	2001, 2005	15/16	52.8	31 to 101	11 to 11	Normal	53.1	KM Mean	63.9	95% KM (t) UCL
	Perch	2001	0/6	ND	---	10 to 11	---	---	---	---	---
	Salmon	2001, 2005 and 2012	36/37	122	16.3 to 280	9.6 to 9.6	Normal	122	KM Mean	140	95% KM (t) UCL
	Trout	2003, 2005 and 2012	54/57	42.9	5.7 to 220	9.7 to 9.7	Gamma	43.0	KM Mean	55.7	95% GROS Approximate Gamma UCL
	Walleye	2005	6/6	3.90	1.7 to 6	---	Normal	---	---	5.07	95% Student's-t UCL
Post Falls Dam to Upriver Dam	All Gamefish	2003, 2005, and 2012	8/8	42.4	25.4 to 68	---	Normal	---	---	51.2	95% Student's-t UCL
	Trout	2003, 2005 and 2012	8/8	42.4	25.4 to 68	---	Normal	---	---	51.2	95% Student's-t UCL
Upriver Dam to Nine Mile Dam	All Gamefish	2003, 2005 and 2012	54/54	87.1	9.7 to 280	---	Gamma	---	---	108	95% Approximate Gamma UCL
	Salmon	2005 and 2012	18/18	163	53.9 to 280	---	Normal	---	---	183	95% Student's-t UCL
	Trout	2003, 2005, and 2012	36/36	49.3	9.7 to 220	---	Gamma	---	---	63.8	95% Adjusted Gamma UCL
Nine Mile Dam to Long Lake Dam	All Gamefish	2001, 2005, and 2012	35/43	60.9	16.3 to 213	9.6 to 11	Gamma	61.8	KM Mean	76.9	KM Adjusted Gamma UCL
	Bass	2001, 2005	15/16	52.8	31 to 101	11 to 11	Normal	53.1	KM Mean	63.9	95% KM (t) UCL
	Perch	2001	0/6	ND	---	10 to 11	---	ND	---	---	
	Salmon	2001, 2005, and 2012	18/19	83.0	16.3 to 213	9.6 to 9.6	Normal	83.3	KM Mean	106	95% KM (t) UCL
	Trout	2005 and 2012	2/2	83.5	37 to 130	---	---	---	---	---	
Long Lake Dam to Lake Roosevelt	All Gamefish	2012	3/6	21.3	15.4 to 59	9.7 to 9.7	Normal	23.8	KM Mean	42.8	95% KM (t) UCL
	Trout	2012	3/6	21.3	15.4 to 59	9.7 to 9.7	Normal	23.8	KM Mean	42.8	95% KM (t) UCL
Lake Roosevelt	All Gamefish	2005	11/11	5.61	1.7 to 10.8	---	Normal	---	---	7.06	95% Student's-t UCL
	Trout	2005	5/5	7.66	5.7 to 10.8	---	Gamma	---	---	9.87	95% Student's-t UCL
	Walleye	2005	6/6	3.90	1.7 to 6	---	Normal	---	---	5.07	95% Student's-t UCL

Notes:

All concentration units are in ppb_{ww}.

Half-DL Arithmetic Mean, KM Mean values and 95^{th}% UCL values are rounded to three significant digits in this table.

Total PCBs are based on the sum of the detected Aroclor PCBs or sum of detected PCB congeners.

Sample-field duplicate pairs were averaged for the fish tissue total PCB calculations.

Frequency of detection: The ratio of the counts of detected results and the total number of results.

A dash ('---") indicates that the value was not calculated or not required.

DL = detection limit

ND = not detected

PCB = polychlorinated biphenyl

PRA = probabilistic risk assessment

UCL = upper confidence limit

[a] KM Mean is the Kaplan-Meier Mean concentration that was calculated by EPA's ProUCL software (v 5.1) when the detection frequency is less than 100%.

[b] The 95UCL is the 95^{th} percentile upper confidence limit for the arithmetic mean concentration that was calculated using EPA's ProUCL software (v 5.1).

APPENDIX C

SELECT TABLES FROM EXPERT REPORT OF DAVID SUNDING, PH.D.

PREFACE

This appendix provides select tables from Dr. David Sunding's expert report that were used to support my assessment.

List of Appendix C Tables

Table 3: Estimated Number of Visitors by Activity

Quantile	All Visits	Walking, Running, Biking	Picnicing, Senic View	Fishing	Swimming	Motorized Boating	Non-Motorized Boating	Going to Beach	Inner Tubing	Other
	Number of Households Engaged in Activity									
	320,500	239,500	123,100	40,000	64,900	26,900	43,100	11,000	16,600	9,000
	[308,100, 332,900]	[223,800, 255,100]	[108,100, 138,000]	[30,300, 49,700]	[52,900, 76,800]	[18,800, 35,100]	[33,100, 53,200]	[5,700, 16,300]	[10,100, 23,100]	[4,200, 13,800]
	(81.8%)	*(61.1%)*	*(31.4%)*	*(10.2%)*	*(16.6%)*	*(6.9%)*	*(11.0%)*	*(2.8%)*	*(4.2%)*	*(2.3%)*
	Number of Annual Visits Per Activity									
Mean	30.0	11.0	5.0	4.0	6.0	3.0	4.0	1.0	1.0	2.0
	[24.2, 35.8]	[8.6, 13.7]	[3.1, 6.9]	[1.9, 5.2]	[3.9, 7.7]	[1.1, 4.3]	[2.2, 5.2]	[0.5, 1.9]	[0.8, 2.1]	[0.4, 2.9]
50%	5.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	[3.7, 6.3]	[0.6, 1.4]	[0.0, 0.0]	[0.0, 0.0]	[0.0, 0.0]	[0.0, 0.0]	[0.0, 0.0]	[0.0, 0.0]	[0.0, 0.0]	[0.0, 0.0]
90%	60.0	26.0	5.0	1.0	10.0	0.0	2.0	0.0	0.0	0.0
	[14.7, 105.3]	[5.0, 47.0]	[2.1, 7.9]	[0.0, 3.1]	[0.0, 21.3]	[0.0, 0.4]	[0.0, 9.3]	[0.0, 2.1]	[0.0, 4.5]	[0.0, 0.0]
95%	200.0	60.0	15.0	10.0	40.0	5.0	21.0	0.0	0.0	0.0
	[117.9, 282.1]	[21.1, 98.9]	[0.9, 29.1]	[0.0, 26.4]	[8.7, 71.3]	[0.0, 12.3]	[0.0, 51.5]	[0.0, 24.9]	[0.0, 31.3]	[0.0, 0.0]
99%	365.0	182.5	182.5	182.5	132.5	175.0	100.0	50.0	50.0	75.0
	[355.8, 365.0]	[152.2, 212.8]	[105.1, 259.9]	[74.8, 290.2]	[60.1, 204.9]	[30.3, 319.7]	[41.9, 158.1]	[4.6, 95.4]	[14.2, 85.8]	[0.0, 188.5]

Source and notes: This table calculates the number of visitors to the Spokane River who engage in different recreational activities and their average number of visits per activity each year. Estimates based on responses to questions to Q5 and Q6 of the Robinson Research (2015) Spokane River Water Quality Survey. Where respondents identified more than one activity, I make the assumption that individuals divide the total number of trips equally between all of those activities. Populations are reweighted to reflect populations in the Census Bureau (2015) American Community Survey data. Square brackets calculate the 95% confidence intervals of each estimate.

Appendix Table 1: Fish Consumption Rates by Behavior – Additional Quantiles

	All adult residents	Residents who **visit** the Spokane River	Residents who **fish** the Spokane River	Residents who **consume fish** from the Spokane River
N	391,800	319,500	40,000	30,600
% of Population	100.0%	81.5%	10.2%	7.8%
	Fish Consumption Rate (g/day)			
Mean	0.34	0.42	2.16	4.38
1%	0.00 [0.00, 0.00]	0.00 [0.00, 0.00]	0.00 [0.00, 0.00]	0.00 [0.00, 0.00]
5%	0.00 [0.00, 0.00]	0.00 [0.00, 0.00]	0.00 [0.00, 0.00]	0.00 [0.00, 0.00]
10%	0.00 [0.00, 0.00]	0.00 [0.00, 0.00]	0.00 [0.00, 0.00]	0.00 [0.00, 0.00]
15%	0.00 [0.00, 0.00]	0.00 [0.00, 0.00]	0.00 [0.00, 0.00]	0.00 [0.00, 0.47]
20%	0.00 [0.00, 0.00]	0.00 [0.00, 0.00]	0.00 [0.00, 0.00]	0.00 [0.00, 0.62]
25%	0.00 [0.00, 0.00]	0.00 [0.00, 0.00]	0.00 [0.00, 0.00]	0.47 [0.00, 0.93]
30%	0.00 [0.00, 0.00]	0.00 [0.00, 0.00]	0.00 [0.00, 0.00]	0.93 [0.37, 1.24]
35%	0.00 [0.00, 0.00]	0.00 [0.00, 0.00]	0.00 [0.00, 0.00]	0.93 [0.47, 1.24]
40%	0.00 [0.00, 0.00]	0.00 [0.00, 0.00]	0.00 [0.00, 0.00]	0.93 [0.93, 1.86]
45%	0.00 [0.00, 0.00]	0.00 [0.00, 0.00]	0.00 [0.00, 0.00]	1.40 [0.93, 1.96]
50%	0.00 [0.00, 0.00]	0.00 [0.00, 0.00]	0.00 [0.00, 0.09]	1.86 [1.10, 2.49]
55%	0.00 [0.00, 0.00]	0.00 [0.00, 0.00]	0.00 [0.00, 0.62]	1.86 [1.40, 2.80]
60%	0.00 [0.00, 0.00]	0.00 [0.00, 0.00]	0.00 [0.00, 0.93]	2.49 [1.86, 3.71]
65%	0.00 [0.00, 0.00]	0.00 [0.00, 0.00]	0.62 [0.00, 1.40]	2.80 [2.33, 4.19]
70%	0.00 [0.00, 0.00]	0.00 [0.00, 0.00]	0.93 [0.00, 1.86]	3.73 [2.80, 4.66]
75%	0.00 [0.00, 0.00]	0.00 [0.00, 0.00]	1.55 [0.50, 2.80]	4.35 [3.11, 6.96]
80%	0.00 [0.00, 0.00]	0.00 [0.00, 0.00]	2.33 [1.24, 3.73]	5.59 [4.35, 8.08]
85%	0.00 [0.00, 0.00]	0.00 [0.00, 0.00]	3.73 [1.86, 6.21]	7.92 [4.66, 9.52]
90%	0.00 [0.00, 0.00]	0.00 [0.00, 0.93]	6.21 [3.73, 9.32]	10.10 [8.08, 15.53]
95%	0.93 [0.00, 2.36]	1.55 [0.25, 3.11]	10.10 [7.92, 15.53]	16.78 [12.43, 21.75]
99%	8.70 [5.97, 11.18]	9.94 [7.77, 14.55]	24.85 [20.97, 37.28]	38.84 [27.77, 46.60]
Max	233.04	156.59	156.58	156.58

Source and notes:
This table contains additional quantile estimates of the results in Table 6.
Mean fish consumption rate and quantiles of the fish consumption rate among different subsets of the adult population of three Washington counties, Spokane, Stevens and Lincoln counties, adjacent to the Spokane River. Estimates are calculated based on the population demographics in Table 3 and responses to part D of the Industrial Economics (2013) Upper Columbia River Survey. The model assumes that rates of fish consumption are similar among anglers on the Spokane River as on Lake Roosevelt within each demographic control group. Standard Errors in square brackets are calculated by bootstrap.
[1]: In this column fish consumption rates are calculated among the entire population of Spokane, Lincoln and Stevens Counties.
[2]: In this column, fish consumption rates are calculated among the subset of the population of these counties who visit the Spokane River in a typical year.
[3]: In this column, fish consumption rates are calculated among the subset of the population who fish from the Spokane River.
[4]: In this column, fish consumption rates are calculated among the subset of the population who consume fish from the Spokane River in a typical month.

Appendix Table 3: Species Preference (Separating Perch Group)

	Species share	Mean species FCR (g / day)
Walleye group	50.4%	1.09
	[45.1%, 56.3%]	[0.97, 1.22]
Trout group	35.3%	0.76
	[30.0%, 40.0%]	[0.65, 0.86]
Bass group	7.1%	0.15
	[4.4%, 10.4%]	[0.10, 0.22]
Salmon group	6.3%	0.14
	[4.5%, 7.9%]	[0.10, 0.17]
Perch group	0.4%	0.01
	[0.2%, 0.7%]	[0.00, 0.01]
Other	0.6%	0.01
	[0.3%, 1.0%]	[0.01, 0.02]
Total	100%	2.16

Source and notes: This table calculates the average species composition of fish consumed from the Spokane River in three adjacent Washington counties. Estimates are calculated based on the population demographics in Table 3 and responses to part D of the Industrial Economics (2013) Upper Columbia River Survey. Fish are categorized into groups as requested by Counsel. The model assumes that rates of species-specific fish consumption are similar among anglers on the Spokane River as on Lake Roosevelt within each demographic control group. Standard Errors in square brackets are calculated by bootstrap.

Appendix Table 5: Inferred Child Fish Consumption Rate - Additional Quantiles

	All adult residents who fish the Spokane River	Anglers who **share with children**	Inferred rate: **angler's children** who cosume fish
% of Population	10.2% [7.3%, 13.5%]	2.0% [7.3%, 13.5%]	
Mean	2.16	3.22	0.97
1%	0.00 [0.00, 0.00]	0.00 [0.00, 0.00]	0.00 [0.00, 0.00]
5%	0.00 [0.00, 0.00]	0.00 [0.00, 0.00]	0.00 [0.00, 0.00]
10%	0.00 [0.00, 0.00]	0.00 [0.00, 0.00]	0.00 [0.00, 0.00]
15%	0.00 [0.00, 0.00]	0.00 [0.00, 0.00]	0.00 [0.00, 0.00]
20%	0.00 [0.00, 0.00]	0.00 [0.00, 0.00]	0.00 [0.00, 0.00]
25%	0.00 [0.00, 0.00]	0.00 [0.00, 0.00]	0.00 [0.00, 0.00]
30%	0.00 [0.00, 0.00]	0.00 [0.00, 0.00]	0.00 [0.00, 0.00]
35%	0.00 [0.00, 0.00]	0.00 [0.00, 0.00]	0.00 [0.00, 0.00]
40%	0.00 [0.00, 0.00]	0.00 [0.00, 0.00]	0.00 [0.00, 0.00]
45%	0.00 [0.00, 0.00]	0.00 [0.00, 0.00]	0.00 [0.00, 0.00]
50%	0.00 [0.00, 0.09]	0.00 [0.00, 0.00]	0.00 [0.00, 0.00]
55%	0.00 [0.00, 0.62]	0.00 [0.00, 0.93]	0.00 [0.00, 0.28]
60%	0.00 [0.00, 0.93]	0.00 [0.00, 1.24]	0.00 [0.00, 0.37]
65%	0.62 [0.00, 1.40]	0.93 [0.00, 2.80]	0.28 [0.00, 0.84]
70%	0.93 [0.00, 1.86]	1.55 [0.00, 3.26]	0.47 [0.00, 0.98]
75%	1.55 [0.50, 2.80]	3.11 [0.00, 4.22]	0.93 [0.00, 1.27]
80%	2.33 [1.24, 3.73]	4.19 [1.40, 7.92]	1.26 [0.42, 2.38]
85%	3.73 [1.86, 6.21]	6.99 [3.11, 9.94]	2.10 [0.93, 2.98]
90%	6.21 [3.73, 9.32]	9.32 [4.61, 12.43]	2.80 [1.38, 3.73]
95%	10.10 [7.92, 15.53]	14.91 [9.32, 22.03]	4.47 [2.80, 6.61]
99%	24.85 [20.97, 37.28]	37.28 [24.23, 69.08]	11.18 [7.27, 20.72]
Max	156.58	156.58	46.97

Source and notes:
This table contains additional quantile estimates of the results in Table 9
This table calculates the number of adults who share fish with children in three Washington counties adjacent to the Spokane River, as well as the child's mean fish consumption rate and quantiles of the fish consumption rate. The estimates of the number of adults who share their fish with children are calculated from a logit model based on responses to question D10 in the Industrial Economics (2013) Upper Columbia River Survey. These responses are projected onto the population demographics reported in Table 3. Child fish consumption rates are estimated based on a child to adult consumption ratio of 0.3 to 1. These ratios are based on the national NHANES database. This model assumes that rates of fish consumption are similar among anglers on the Spokane River as on Lake Roosevelt within each demographic control group. Standard Errors in square brackets are calculated by bootstrap